DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Table 1.—*Resources of Mammoth coal, in millions of short tons*

[Posted tonnages and their sums are rounded to three significant figures, with the exception that values less than one have only two significant figures. Leaders (—), no coal in this category]

A.—Calculated according to USGS method (Wood and others, 1983)

B.—Calculated according to kriging method (table adapted from Pierce and others, 1983)

Coal split	County	Township	Measured 2.5–5 ft, overburden 0–200	Measured 2.5–5, >200–500	Measured 2.5–5, >500	Measured 2.5–5, Total	Measured >5–10, 0–200	Measured >5–10, >200–500	Measured >5–10, >500	Measured >5–10, Total	Measured >10–20, 0–200	Measured >10–20, >200–500	Measured >10–20, >500	Measured >10–20, Total	Measured TOTAL	Indicated 2.5–5, 0–200	Indicated 2.5–5, >200–500	Indicated 2.5–5, >500	Indicated 2.5–5, Total	Indicated >5–10, 0–200	Indicated >5–10, >200–500	Indicated >5–10, >500	Indicated >5–10, Total	Indicated >10–20, 0–200	Indicated >10–20, >200–500	Indicated >10–20, >500	Indicated >10–20, Total	Indicated TOTAL	Inferred 2.5–5, 0–200	Inferred 2.5–5, >200–500	Inferred 2.5–5, >500	Inferred 2.5–5, Total	Inferred >5–10, 0–200	Inferred >5–10, >200–500	Inferred >5–10, >500	Inferred >5–10, Total	Inferred >10–20, 0–200	Inferred >10–20, >200–500	Inferred >10–20, >500	Inferred >10–20, Total	Inferred TOTAL	TOTAL	B: Resources (95 percent confidence interval may be computed using number in parentheses), Thickness (ft) 2.5–5	B: >5–10	B: >10–20	B: TOTAL
Mammoth 1	Musselshell	8N, 26E	—	—	—	0	0.32	0.14	—	0.46	—	—	—	0	0.46	—	—	—	0	0.18	—	—	0.18	—	—	—	0	0.18	—	—	—	0	—	—	—	0	—	—	—	0	0	0.62	—	—	—	0
		8N, 27E	—	—	—	0	0.64	—	—	0.64	—	—	—	0	0.64	0.18	—	—	0.18	0.20	—	—	0.20	—	—	—	0	0.38	—	—	—	0	—	—	—	0	—	—	—	0	0	1.00	—	1.04 (±0.16)	—	1.04
		8N, 28E	1.37	—	—	1.37	2.21	—	—	2.21	—	—	—	0	3.58	7.71	1.60	—	9.31	3.15	0.45	—	3.60	—	—	—	0	12.9	5.23	8.39	0.18	13.8	—	—	—	0	—	—	—	0	13.8	30.3	15.3 (±0.77)	17.1 (±0.86)	—	32.4
		7N, 26E	0.13	—	—	0.13	2.92	5.48	0.11	8.51	—	—	—	0	8.64	3.70	0.29	—	3.99	4.94	9.72	0.56	15.2	—	—	—	0	19.2	8.57	0.06	—	8.63	1.37	—	—	1.37	—	—	—	0	10.0	37.8	—	43.8 (±1.74)	—	43.6
		7N, 27E	4.30	0.16	—	4.46	6.90	0.88	—	7.78	—	—	—	0	12.2	8.30	0.32	—	8.62	2.05	0.45	—	2.50	—	—	—	0	11.1	2.93	—	—	2.93	0.07	—	—	0.07	—	—	—	0	3.00	26.3	4.28 (±0.17)	24.2 (±0.97)	—	28.5
		TOTAL	18.8	15.9	1.93	36.6	97.0	60.4	8.86	166	64.5	53.0	21.1	158	361	34.7	23.7	1.87	60.3	151	56.3	12.7	220	102	112	57.0	271	[2]551	31.2	12.7	0.77	44.7	80.3	21.8	2.88	105	3.67	18.1	13.4	33.1	183	1,100	138	540	439	1,120

[1] Overburden categories approximate. See text.

[2] Due to the vagaries of the rounding process, these column totals differ from the posted row totals in the last digit.

[3] Included but not posted are hypothetical resources—1.86 million short tons for thickness of >5–10 ft with overburden of 0–200 ft.

[4] Included but not posted are hypothetical resources—0.34 million short tons for thickness of >5–10 ft with overburden of 0–200 ft.

[5] These totals include the resources mentioned in footnotes 3 and 4.

[1] Includes resources for T. 8 N., R. 26 E.—0.21 million short tons for thickness of >5–10 ft.

Table 2.—*Proximate, ultimate, and associated analyses of 11 samples of Mammoth coal, compared with Powder River region coal samples*

[Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: 1, as received; 2, moisture free; 3, moisture and ash free. Samples D189148–D189151 analyzed by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa.; D221596–D221599 by U.S. Department of Energy; 5799, 6828, 6831 by U.S. Geological Survey. Values right of brace are weighted average, as-received basis, for upper and lower parts of a coal bed at a single locality. Kcal/kg=0.556 (Btu/lb); °C=(°F−32)÷1.8. Leaders (---), not applicable; ND, not determined]

Locality	Mammoth coal split	Sample No.	Sample type	Form of analyses	Air dry loss (percent)	Proximate: Moisture	Volatile matter	Fixed C	Ash	Ultimate: H	C	N	O	S	Sulfur: Sulfate	Pyritic	Organic	Fusibility of ash (°F)[1]	Heat of combustion (Btu/lb)	Heat of combustion (Btu/lb), moist, mineral-matter free	Apparent rank[2]
84-C79	Mammoth 1+2 upper 5 ft	D189151		1	1.8	17.1	32.7	41.7	8.5	5.8	56.7	1.0	27.0	1.0	0.01	0.35	0.63	2,400	9,850		
				2	---	---	39.5	50.3	10.2	4.7	68.5	1.2	14.2	1.2	.01	.43	.76	2,490	11,890		
				3	---	---	44.0	56.0	---	5.3	78.3	1.3	15.8	1.3	.01	.48	.85	2,575	13,240		
						17.4	32.2	43.2	7.2	5.9	57.8	1.0	27.2	0.8	0.01	0.36	0.50		10,070	10,950	hvCb or subA
	lower 5 ft	D189150	channel (Divide Mine)	1	2.9	17.6	31.8	44.8	5.8	6.0	50.0	1.0	27.4	.7	.01	.38	.37	2,255	10,290		
				2	---	---	38.6	54.3	ND	5.0	71.7	1.2	14.3	.9	.01	.44	.45	2,345	12,500		
				3	---	---	41.6	58.4	---	5.3	77.1	1.3	15.3	1.0	.01	.47	.48	2,425	13,440		
84-C78	Mammoth 1+2 upper 3.4 ft	D189149		1	2.4	16.3	32.4	42.8	8.5	5.7	58.0	0.9	28.0	0.9	0.01	0.48	0.42	2,195	10,040		
				2	---	---	38.7	51.2	10.1	4.7	69.3	1.1	13.8	1.1	.01	.55	.50	2,280	11,990		
				3	---	---	43.1	56.9	---	5.2	77.1	1.2	15.4	1.2	.01	.61	.56	2,380	13,340		
						16.6	32.6	44.0	6.8	5.9	59.1	1.0	28.2	1.1	0.01	0.64	0.44		10,290	11,140	hvCb or subA
	lower 5 ft	D189148	channel (PM Mine)	1	2.6	16.8	32.8	44.8	5.6	6.0	59.9	1.0	28.4	1.2	.01	.76	.45	2,135	10,460		
				2	---	---	39.4	53.9	6.7	4.9	72.0	1.2	13.8	1.5	.01	.91	.54	2,215	12,570		
				3	---	---	42.2	57.8	---	5.3	77.1	1.3	14.8	1.6	.01	.98	.58	2,305	13,470		
85-68C	Mammoth 1+2+3 upper 6.7 ft	D221596		1	ND	9.6	32.3	48.8	8.8	5.2	63.1	1.1	20.9	0.8	0.01	0.43	0.41	2,350	10,990		
				2	---	---	36.3	53.9	9.8	4.6	69.8	1.2	13.7	.9	.01	.48	.46	2,440	12,150		
				3	---	---	40.2	59.8	---	5.1	77.4	1.3	15.2	1.0	.01	.53	.50	2,530	13,470		
						10.2	32.5	48.6	8.8	5.2	62.7	1.1	21.5	0.7	0.01	0.34	0.39		10,900[3]	12,080	hvCb
	lower 6.3 ft	D221597	core	1	ND	10.8	32.1	48.3	8.8	5.3	62.2	1.1	22.1	.6	.01	.25	.37	2,470	10,800		
				2	---	---	36.0	54.2	9.8	4.6	69.7	1.2	14.0	.7	.01	.28	.41	2,560	12,100		
				3	---	---	39.9	60.1	---	5.1	77.3	1.3	15.8	.8	.01	.31	.45	2,670	13,420		
85-79N	Mammoth 1+2+3 upper 7.9 ft	D221598		1	ND	11.3	31.0	48.4	8.3	5.3	62.7	1.0	21.7	0.9	0.01	0.55	0.37	2,180	10,780		
				2	---	---	34.9	55.7	9.4	4.6	70.7	1.1	13.1	1.0	.01	.62	.41	2,240	12,160		
				3	---	---	38.5	61.5	---	5.0	78.1	1.2	14.5	1.2	.01	.69	.46	2,330	13,420		
						10.8	31.6	48.3	9.2	5.3	62.2	1.0	21.4	0.8	0.01	0.46	0.34		10,730[3]	11,950	hvCb
	lower 6.4 ft	D221599	core	1	ND	10.3	32.4	46.9	10.4	5.3	61.6	1.1	21.0	.7	.01	.35	.31	2,620	10,680		
				2	---	---	36.1	52.3	11.6	4.7	68.6	1.2	13.2	.7	.01	.39	.35	2,710	11,900		
				3	---	---	40.8	59.2	---	5.3	77.6	1.3	15.0	.8	.01	.44	.39	2,790	13,480		
[illegible]	Mammoth 1+2 lower 7 ft of 8.4 ft	[4]5799	channel	1	ND	17.4	31.2	45.1	6.3	5.4	59.0	0.9	27.8	0.5	ND	ND	ND	ND	10,120	10,880	hvCb or subA
[illegible]	Mammoth 2+3 lower 6 ft of upper 8.6 ft	[4]6831	channel	1	ND	17.4	31.2	48.1	3.3	ND	ND	ND	ND	0.4	ND	ND	ND	ND	10,280		
	lower 5 ft	[4]6828	channel	1	ND	18.7	29.6	46.6	5.1	ND	ND	ND	ND	.8	ND	ND	ND	ND	9,890		
						18.0	30.6	47.4	4.1					0.6					10,100	10,580	hvCb or subA
	Arithmetic mean, Mammoth coal samples[5]		---	1	ND	15.1	31.8	48.1	7.1	5.5	60.2	1.0	24.8	0.8	0.01	0.45	0.42	2,320 2,400 2,490	10,370	11,200	hvCb or subA
	Arithmetic mean, 13 Powder River region coal samples[6]		---	1	16.1	27.1	28.7	38.4	7.9	6.3	48.5	0.7	35.2	1.4	0.01	1.18	0.21	ND	8,370	9,180	subC

[1] The three numbers for each analysis are, in sequence, initial deformation of ash temperature, softening temperature, and fluid temperature.

[2] hvCb=high-volatile C bituminous; subA=subbituminous A; subC=subbituminous C. Computed according to standards of American Society for Testing and Materials (1973).

[3] These figures may not be accurate, as the samples were not analyzed immediately and may have dried somewhat. These are splits of samples from a private company. Values reported here are about 10 percent higher than company values. The rank, however, remains the same.

[4] These analyses are reported in Woolsey and others (1917, p. 53).

[5] Calculated using weighted average for each locality.

[6] Derived from Swanson and others (1976, table 31B). "Powder River region" of Swanson and others is from Trumbull (1960), and is approximately equivalent to the Powder River basin.

Table 3.—*Major- and minor-oxide and trace-element compositions of the laboratory ash of eight coal samples from the Mammoth coal, compared with Powder River region coal samples*

[Coals were ashed at 525°C. L, less than value shown; N, not detected; leaders (---), not determined; -S, values listed were determined by semiquantitative spectrographic analysis. Spectrographic results for samples D189148–D189151 are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are reported arbitrarily as midpoints of those brackets, 1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. Precision of spectrographic data is approximately one bracket at 68-percent confidence, or two brackets at 95-percent confidence; confidence of values for samples D221596–D221599 ranges between plus 50 percent and minus 33 percent]

Locality	Mammoth coal split	Sample No.	Ash (percent)	SiO_2 (percent)	Al_2O_3 (percent)	CaO (percent)	MgO (percent)	Na_2O (percent)	K_2O (percent)	Fe_2O_3 (percent)	TiO_2 (percent)	SO_3 (percent)	Ag-S ppm	B-S ppm	Ba-S ppm	Be-S ppm	Cd ppm	Ce-S ppm	Cu ppm	Ga-S ppm	Ge-S ppm	La-S ppm	Li ppm	Mn ppm	Mo-S ppm	Nb-S ppm	Ni-S ppm	Pb ppm	Sc-S ppm	Sr-S ppm	V-S ppm	Y-S ppm	Yb-S ppm	Zn ppm	Zr-S ppm
84-C79	Mammoth 1+2 upper 5 ft	D189151	8.4	32	20	11	1.9	0.23	0.27	8.8	1.0	12	N	500	5,000	5	1.0	N	95	20	N	N	150	380	10	N	30	35	15	2,000	70	50	5	180	200
	lower 5 ft	D189150	7.1	34	22	7.7	2.7	.28	.35	11	.87	11	N	500	5,000	7	1.0L	N	93	30	N	N	130	510	10	N	15	50	10	1,500	70	50	5	75	150
84-C78	Mammoth 1+2 upper 3.4 ft	D189149	10.5	29	17	23	1.7	0.18	0.23	7.3	0.85	8.7	N	200	3,000	N	1.0L	N	82	20	N	N	87	620	10	N	15	45	10	1,500	70	50	5	78	150
	lower 5 ft	D189148	6.6	24	16	14	2.4	.18	.29	17	.83	12	N	500	7,000	10	1.0L	N	78	30	20	70	70	420	20	N	10	40	20	2,000	70	70	7	44	150
85-68C	Mammoth 1+2+3 upper 6.7 ft	D221596	8.9	41	25	6.0	1.2	2.8	0.37	7.3	0.94	---	0.92L	300	5,100	5.7	1.0L	170	66	42	7.4	67	130	370	12	62	27	42	18	2,700	120	82	5.2	120	1,100
	lower 6.3 ft	D221597	9.6	45	29	4.9	1.0	2.4	.42	4.8	.90	---	.92L	340	3,200	8.9	1.0L	190	95	43	12	85	160	330	7.6	62	31	51	21	2,400	160	90	6.1	81	990
85-79N	Mammoth 1+2+3 upper 7.9 ft	D221598	9.2	41	21	5.5	1.5	2.8	0.79	9.0	1.2	---	0.97	350	2,600	6.9	2.0	180	77	38	6.7	64	110	370	16	43	27	25L	15	2,000	150	55	4.9	59	720
	lower 6.4 ft	D221599	12.1	45	28	4.1	.83	1.9	.41	4.9	.92	---	.92L	340	5,700	8.2	1.0L	180	88	57	11	88	130	240	9.1	57	28	48	19	2,100	170	67	5.5	82	750
	Arithmetic mean, Mammoth coal samples[1]		8.9	38	22	9.5	1.7	1.3	0.40	9.0	0.96	11.4	0.93L	390	4,600	7.7L	1.0L	170L	88	34	13L	71L	120	400	12	56L	22	41L	16	2,200	110	62	5.4	85	520
	Arithmetic mean, 410 Powder River region coal samples[2]		9.9	30	14	18	4.0	1.6	0.50	7.3	0.68	17	---	---	---	---	0.8	---	123	---	---	---	58	---	---	---	---	58	---	---	---	---	---	208	---

[1] Calculated using weighted average for each locality.

[2] From Hatch and Swanson (1977, table 6A). "Powder River region" of Hatch and Swanson is from Trumbull (1960), and is approximately equivalent to the Powder River basin.

Table 4.—*Content of 40 elements in eight coal samples from the Mammoth coal, reported on whole-coal basis, compared with Powder River region coal samples*

[As, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) coal; remaining analyses calculated from determinations on ash. -S, content determined by semiquantitative spectrographic analysis (see table 3). L, less than value shown; N, not detected; leaders (---), not determined]

Locality	Mammoth coal split	Sample No.	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	Ag-S ppm	As ppm	B-S ppm	Ba-S ppm	Be-S ppm	Cd ppm	Ce-S ppm	Co ppm	Cr ppm	Cu ppm	F ppm	Ga-S ppm	Ge-S ppm	Hg ppm	La-S ppm	Li ppm	Mn ppm	Mo-S ppm	Nb-S ppm	Ni-S ppm	Pb ppm	Sb ppm	Sc-S ppm	Se ppm	Sr-S ppm	Th ppm	U ppm	V-S ppm	Y-S ppm	Yb-S ppm	Zn ppm	Zr-S ppm
84-C79	Mammoth 1+2 upper 5 ft	D189151	1.3	0.89	0.66	0.094	0.014	0.019	0.50	0.050	N	2.2	50	500	0.5	0.084	N	1.8	2.9	8.0	35	1.5	N	0.11	N	13	32	1	N	2	2.9	0.40	1.5	0.10L	150	1.5	1.2	7	5	0.5	13	15
	lower 5 ft	D189150	1.1	.83	.38	.11	.015	.021	.55	.041	N	1.3	30	300	.5	.071L	N	1.3	2.5	6.6	20L	2	N	.04	N	9.4	36	.7	N	1	3.8	.43	.7	.40	100	1.5	1.1	5	3	.3	5.3	10
84-C78	Mammoth 1+2 upper 3.4 ft	D189149	1.4	0.94	1.7	0.10	0.012	0.020	0.54	0.053	N	3.8	20	300	N	0.11L	N	1.1	3.3	8.7	20	2	N	0.11	N	9.1	65	1	N	1.5	4.7	0.40	1	0.52	150	1.5	1.7	7	5	0.5	8.0	15
	lower 5 ft	D189148	.74	.56	.60	.098	.009	.016	.78	.033	N	3.1	30	500	.7	.066L	N	1.2	2.5	5.1	20L	2	1.5	.07	5	4.6	28	1.5	N	.7	2.8	1.3	1.5	.25	150	1.2	1.4	5	5	.5	2.9	10
85-68C	Mammoth 1+2+3 upper 6.7 ft	D221596	1.7	1.2	0.38	0.084	0.17	0.027	0.45	0.050	0.082L	1.8	27	450	0.51	0.089L	15	0.76	2.9	7.7	20	3.7	0.66	0.12	6.0	12	33	1.1	5.5	2.4	3.7	0.87	1.4	0.98	240	1.9	1.4	11	5.5	0.46	10	98
	lower 6.3 ft	D221597	2.0	1.4	.34	.056	.17	.034	.31	.052	.088L	2.0	33	310	.85	.096L	18	1.1	3.8	9.1	20	4.1	1.2	.07	8.2	15	31	.73	6.0	3.0	4.0	.94	2.0	.74	230	2.2	1.4	15	8.8	.58	5.9	95
85-79N	Mammoth 1+2+3 upper 7.9 ft	D221598	1.7	1.0	0.36	0.081	0.18	0.061	0.58	0.064	0.089	2.1	32	240	0.63	0.18	15	0.75	2.8	7.1	25	3.3	0.82	0.07	5.9	10	34	1.5	4.0	2.5	2.3L	0.46	1.4	0.54	240	1.1	1.2	14	5.1	0.45	5.4	66
	lower 6.4 ft	D221599	2.5	1.8	.35	.080	.17	.041	.41	.087	.11L	1.8	41	690	.90	.12L	22	.97	3.7	11	25	6.9	1.3	.06	8.3	16	29	1.1	6.9	3.1	5.8	1.2	2.3	---	250	2.5	1.4	21	8.1	.87	11	91
	Arithmetic mean, Mammoth coal samples[1]		1.5	1.1	0.66	0.083	0.094	0.030	0.52	0.051	0.086L	2.2	33	410	0.67L	0.10L	17L	1.1	3.0	7.9	23L	3.2	1.1L	0.08	6.4L	11	35	1.1	5.5L	2.1	3.7L	0.74	1.5	0.50L	190	1.6	1.3	10	5.8	0.40	7.5	50
	Arithmetic mean, 410 Powder River region coal samples[2]		1.5	0.78	1.1	0.21	0.11	0.048	0.54	0.041	---	3	70	300	0.7	0.09	---	2	7	11.2	49	3	---	0.11	---	5.9	51	2	1.5	5	6.4	0.6	2	1.0	200	4.3	0.9	15	5	0.5	20	15

[1] Calculated using weighted average for each locality.

[2] From Hatch and Swanson (1977, table 6B). "Powder River region" of Hatch and Swanson is from Trumbull (1960), and is approximately equivalent to the Powder River basin.

INTRODUCTION

The Mammoth coal bed is of subbituminous A to high-volatile C bituminous apparent rank, averaging 12.5 ft thick and underlying an area of 85 mi². It lies about 1,000 ft above the base of the Tongue River Member of the Paleocene Fort Union Formation, as defined by Woolsey and others (1917), in south-central Montana's Bull Mountain basin (figs. 1 and 2). Part A of this Coal Investigations series includes maps showing the outcrop, structure, cross sections, and isopachs of partings of the Mammoth coal bed (Connor, 1988). This part, part B, contains maps showing the geographic location of the boundaries between Mammoth coal splits, isopachs of the splits, and the overburden thickness, and tables showing coal resources and coal quality. The outcrop and locality map of part A is also included here. Available data for all drill holes and most surface localities have been entered in the NCRDS (National Coal Resources Data System) of the U.S. Geological Survey, Reston, VA 22092, and have been published by C. W. Connor and L. R. H. Biewick (USGS Open-File Report 89-6).

SPLITS OF MAMMOTH COAL BED

The Mammoth coal bed is made up of three splits, separated by two partings of fluvial origin that range from less than an inch to more than 50 ft thick. The three splits were designated in part A of this series as, from base to top, Mammoth 1, Mammoth 2, and Mammoth 3. Mammoth 3 is equivalent to the Rehder split of earlier authors (Woolsey and others, 1917). Where these splits join they are designated Mammoth 1+2, Mammoth 2+3, and Mammoth 1+2+3. This is diagrammed in figure 3. Note that geographic boundaries between the various combinations of splits are not drawn where the splits diverge, but (for resource calculation purposes) are drawn where the thickness of a parting exceeds the thickness of either the overlying or underlying coal split. Data points used in determining these boundaries, the outcrop line, and the isopachs are shown in figure 4, and the map locations of the boundary lines and the 200- and 500-ft overburden lines are shown in figure 5.

ISOPACHS OF SPLITS

The splits of the Mammoth coal bed are isopached in figures 6*A–F*. Because the splits can be identified beyond the arbitrary boundaries described above, they are isopached as far beyond those boundaries as they can be recognized (dotted lines). Each of these maps displays all the data points used in constructing that particular map.

The average thicknesses of the Mammoth coal splits, to the nearest half foot, are as follows: Mammoth 1, 5.5 ft; Mammoth 2, 3 ft; Mammoth 3, 2.5 ft; Mammoth 1+2, 9 ft; Mammoth 2+3, 7.5 ft; Mammoth 1+2+3, 13.5 ft.

Two interesting features that suggest the controls on the thicknesses might be pointed out. The uppermost split, Mammoth 3 (fig. 6*C*), overlies a thick parting that has been identified as channel and overbank splay deposits (Connor, 1988). As Mammoth 3 is thickest on the flanks of this deposit (the two long northwest-trending areas more than 2.5 ft thick) and thins over the top of the channel (the linear less than 2-ft-thick area between the thicker areas), and as the configuration and position of the thinner area closely coincides with the thickest (center) part of the underlying channel deposit, environmental control is strongly suggested.

Structural control is suggested in two other isopach maps. Mammoth isopachs generally trend northwest, but in the south-central part of the region, in the southeast corner of the area of Mammoth 1+2 (fig. 6*D*) and in the southern two-thirds of Mammoth 1+2+3 (fig. 6*F*), the trend is northeast. This is the area that contains the thickest coal. The existence of a growth fault is suggested, but it is equally possible that the trend change is an artifact of data distribution.

COAL RESOURCES

The Mammoth coal is commonly oxidized on outcrop, but roadcut exposures of this and other coals in the Bull Mountains give evidence that oxidation has generally progressed only a few tens of feet to a hundred feet or so from the surface. Because coal loss due to oxidation is probably minor, it is not taken into consideration in resource estimates.

Resources reported in table 1*A* were calculated according to guidelines in U.S. Geological Survey Circular 891, "Coal resource classification system of the U.S. Geological Survey" (Wood and others, 1983). According to that currently standard USGS method, "measured" resources lie within a radius of 1/4 mi from a data point, "indicated" resources lie between 1/4 and 3/4 mi from a data point, "inferred" resources lie between 3/4 and 3 mi from a data point, and "hypothetical" resources lie beyond 3 mi from a data point. Although these categories suggest different degrees of certainty in reported values, that certainty cannot be quantified.

By way of contrast, in the kriging method of resource analysis (well described in Mousset-Jones, 1980), tonnage estimates can have confidence limits attached at any desired confidence level—a very desirable attribute. Resources for the Mammoth coal bed have already been reported using that statistical method (Pierce and others, 1983). The estimates according to the kriging method are included here (table 1*B*) but in a different format than in the original publication, for convenience in comparison with the standard USGS results.

Tonnages based on the two resource estimation methods are for the most part similar (last column, tables 1*A* and 1*B*). The totals for Mammoth 1, Mammoth 2, Mammoth 1+2, and Mammoth 1+2+3, as well as the grand total for the Mammoth, are within 2–5 percent of each other. The Mammoth 2+3 totals are within 11 percent. The Mammoth 3 totals differ by 32 percent, for some unknown reason. Comments in the rest of this section refer only to the standard USGS estimates in table 1*A*.

Coal tonnages are reported by split and location in categories according to qualitative degree of certainty, thickness, and overburden. Thickness categories (net coal, partings excluded) are 2.5–5 ft, >5–10 ft, and >10–20 ft. Coal less than 2.5 ft thick is excluded. Overburden categories are 0–200 ft, >200–500 ft, and >500 ft. The coal weight used in the calculations was 1,770 short tons per acre-foot.

Total tonnage for the Mammoth coal bed is estimated at 1.1 billion short tons. Total "measured" resources are 361 million short tons, "indicated" resources are 551 million short tons, and "inferred" resources are 183 million short tons. Tonnages by split and split combinations are, in millions of short tons: Mammoth 1, 121; Mammoth 2, 30.8; Mammoth 3, 46.2; Mammoth 1+2, 434; Mammoth 2+3, 108; and Mammoth 1+2+3, 357. Tonnages by thickness categories are: 2.5–5 ft, 142 million short tons; >5–10 ft, 491 million short tons; and >10–20 ft, 462 million short tons.

Tonnages by overburden category require some explanation. The overburden lines (fig. 5) were drawn relative to the top of the whole Mammoth package (that is, from the top of Mammoth 3, Mammoth 2+3, and Mammoth 1+2+3; see diagram, fig. 3), so resource estimates tabulated by overburden category are best for those splits. There is somewhat more overburden above the other three splits, but this can be ignored for Mammoth 1 and Mammoth 2 because the extra overburden amounts to less than 20 ft over most of their areas. Mammoth 1+2, however, has an extra 30–50 ft of overburden over much of its area (the channel sandstone discussed and isopached in part A), so some of its tabulated resources actually belong in the next thicker overburden category. Total Mammoth resources as reported by overburden category are: 603 million short tons under 0–200 ft of overburden, 372 million short tons under >200–500 ft of overburden, and 120 million short tons under >500 ft of overburden. Maximum overburden is about 800 ft, in the central parts of the two largest 500-ft overburden closures.

The township with the greatest resources is T. 6 N., R. 27 E., with 435 million short tons. Other townships with large resources, 140–180 million short tons, are T. 6 N., R. 28 E., T. 7 N., R. 26 E., and T. 7 N., R. 27 E. The other four townships underlain by the Mammoth coal bed each have less than 100 million short tons.

The possibility of roof problems in mining should be considered particularly for Mammoth 1+2, which is overlain by channel and splay deposits that are in turn overlain by Mammoth 3. Horne and others (1977, p. 89, 96–99) have demonstrated that "where splay deposits occur directly over a minable coal, are less than 20 ft (6 m) thick, and have a rider coal or extensively rooted zone over the top of the splay, severe roof problems may be encountered during mining." About half of Mammoth 1+2 meets these criteria, and that area may be delineated by overlaying the Mammoth 1+2 map (fig. 6*D*) with the isopach of the channel and splay deposits ("upper parting") in part A of this series.

COAL QUALITY

Based on analyses of 11 samples at six localities (table 2), the Mammoth coal contains an average (arithmetic mean) of 31.8 percent volatile matter, 7.1 percent ash, and 0.8 percent sulfur, about half of which is pyritic and half organic. Its apparent rank is subbituminous A to high-volatile C bituminous, as the heat of combustion on an as-received, moist, mineral-matter-free basis ranges from 10,580 to 12,080 Btu/lb and averages 11,260 Btu/lb. Vitrinite reflectance values of 0.4–0.5 percent (Daniel, 1982) on coal samples from the same localities as the first four localities listed on table 2 indicate the same range in apparent rank reported here. The relationship of vitrinite reflectance to coalification stages is discussed in Davis (1978) and summarized on table 4 of that publication.

The Mammoth coal of the Bull Mountain basin is of higher quality than Powder River basin coals deposited at about the same time, before the individual basins formed. Mammoth coal is of higher apparent rank (Powder River region coals are, on the average, subbituminous C), and the sulfur content is about half that of the Powder River region coal (table 2, last row). Furthermore, trace-element analyses of eight Mammoth coal samples from four localities (tables 3 and 4), when compared with Powder River region coal samples (last row, both tables), show that the Mammoth samples have about half as much of the commonly considered potentially toxic B, F, Mo, Pb, and Se. Toxicity hazards from environmental concentrations of these elements are discussed in Gough and others (1979). There may be fewer such hazards with the Mammoth coal than with the Powder River region coals. Only two elements occur in the Mammoth samples in considerably greater concentration than in the Powder River region (in fact, they are three to four times more abundant): Nb and Zr. The larger amounts of these elements, probably held in the heavy minerals, may be due to the Mammoth coal bed area having been closer to early Tertiary sources of volcanic ash than the Powder River area. Nb and Zr are unlikely environmental hazards.

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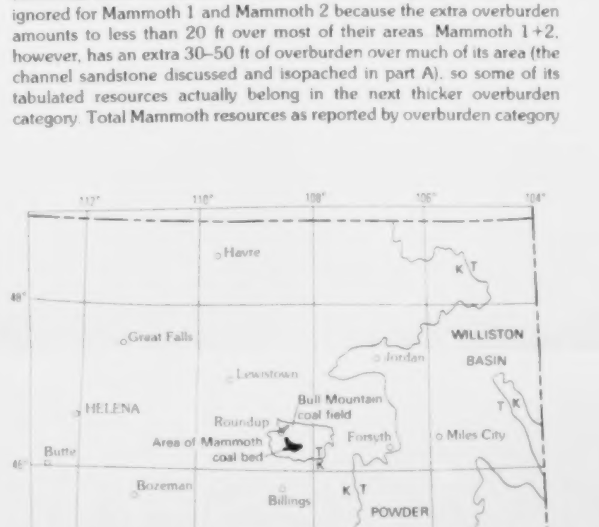


Figure 1.—Location of Mammoth coal bed, south-central Montana. Bull Mountain coal field and Powder River basin and Williston basin boundaries drawn at K-T (Cretaceous-Tertiary) boundary. Modified from American Association of Petroleum Geologists (1972).

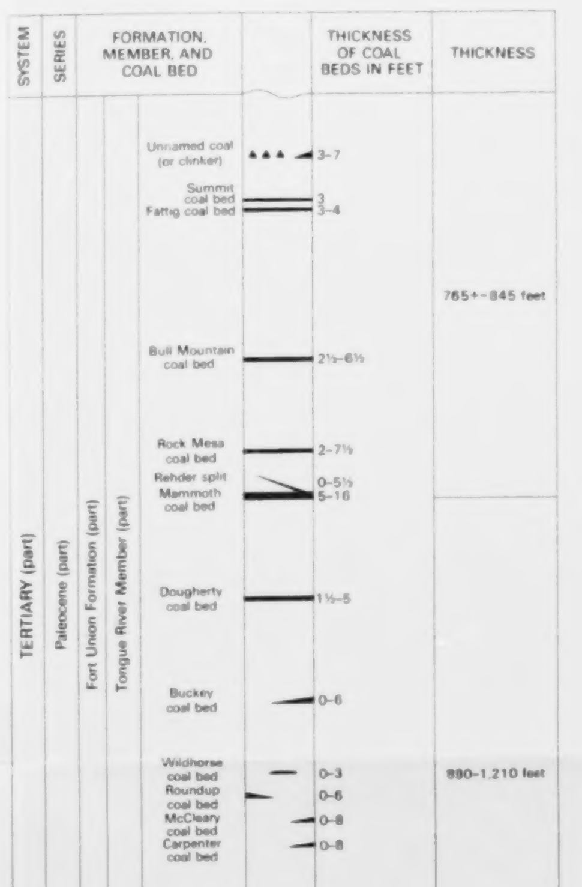


Figure 2.—Stratigraphic position of the Mammoth coal bed and other relatively persistent coal beds in the Bull Mountain coal field. Modified from Woolsey and others (1917).

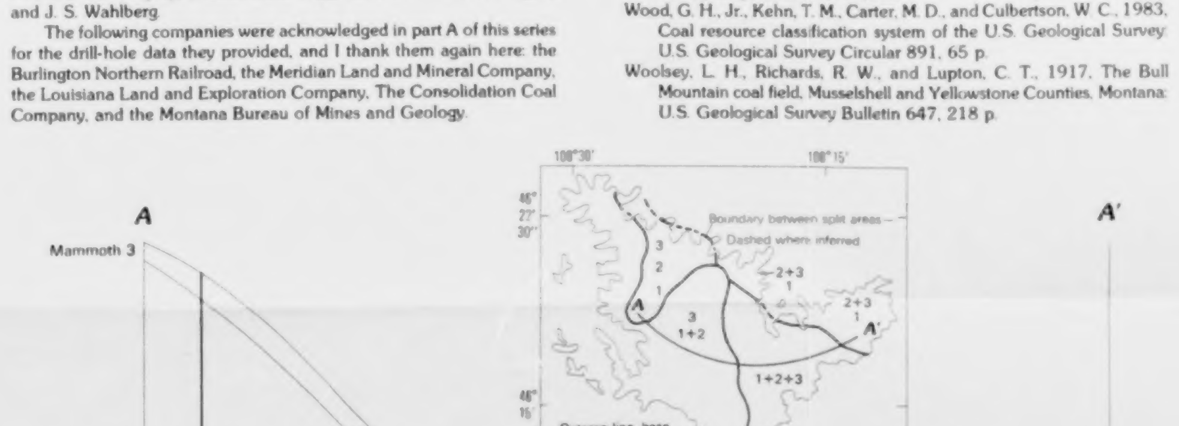

A
A′
Mammoth 3
Mammoth 2
Mammoth 1
3
1+2
1+2+3
2+3
1
Boundary between split areas
108°30′
108°15′
46°27′30″
46°15′
Boundary between split areas—Dashed where inferred
Outcrop line, base of Mammoth coal bed

Figure 3.—Generalized cross section (see inset for location) showing designations of Mammoth coal splits. Note that the boundaries between split areas are drawn where a parting exceeds the thickness of the split either above or below.

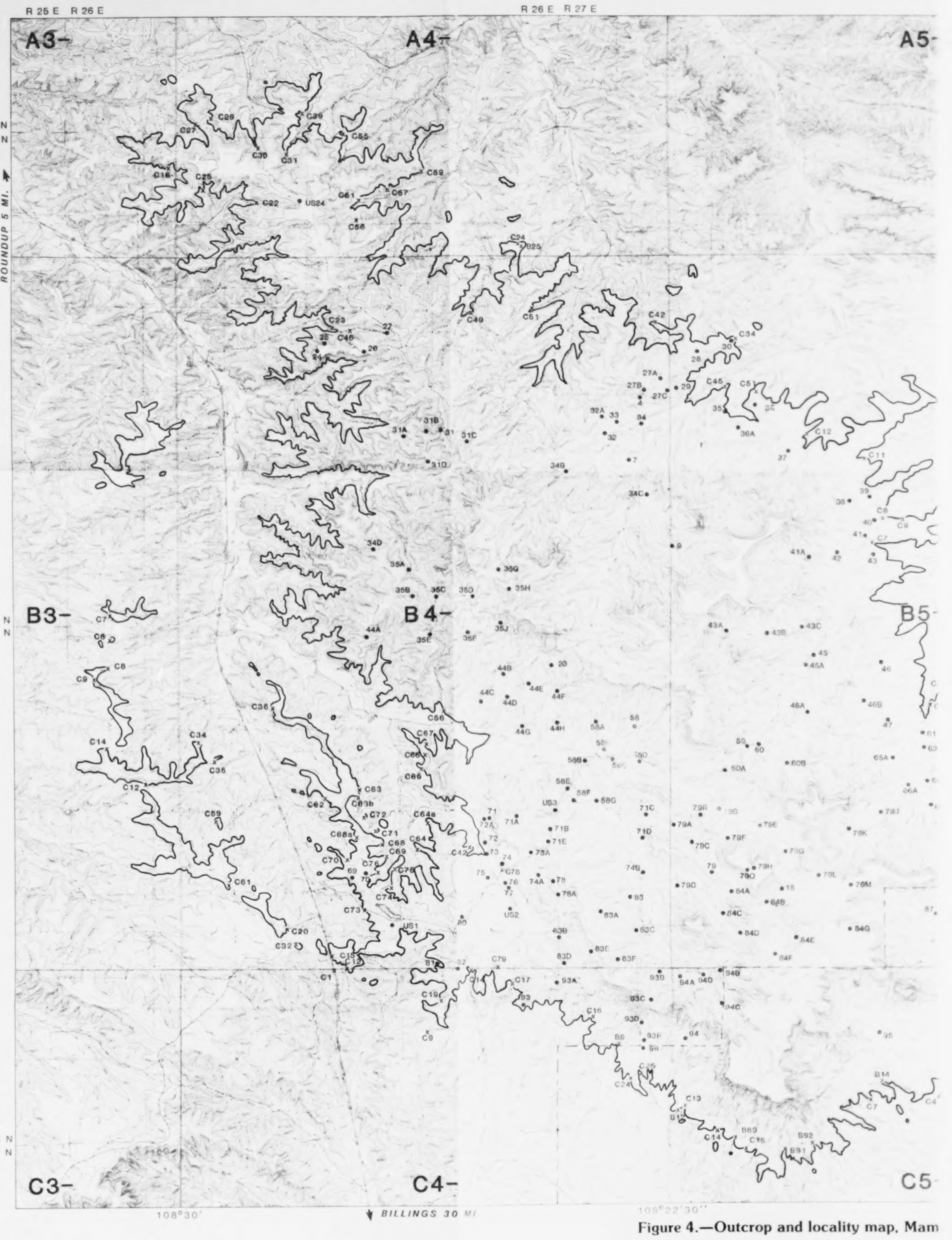
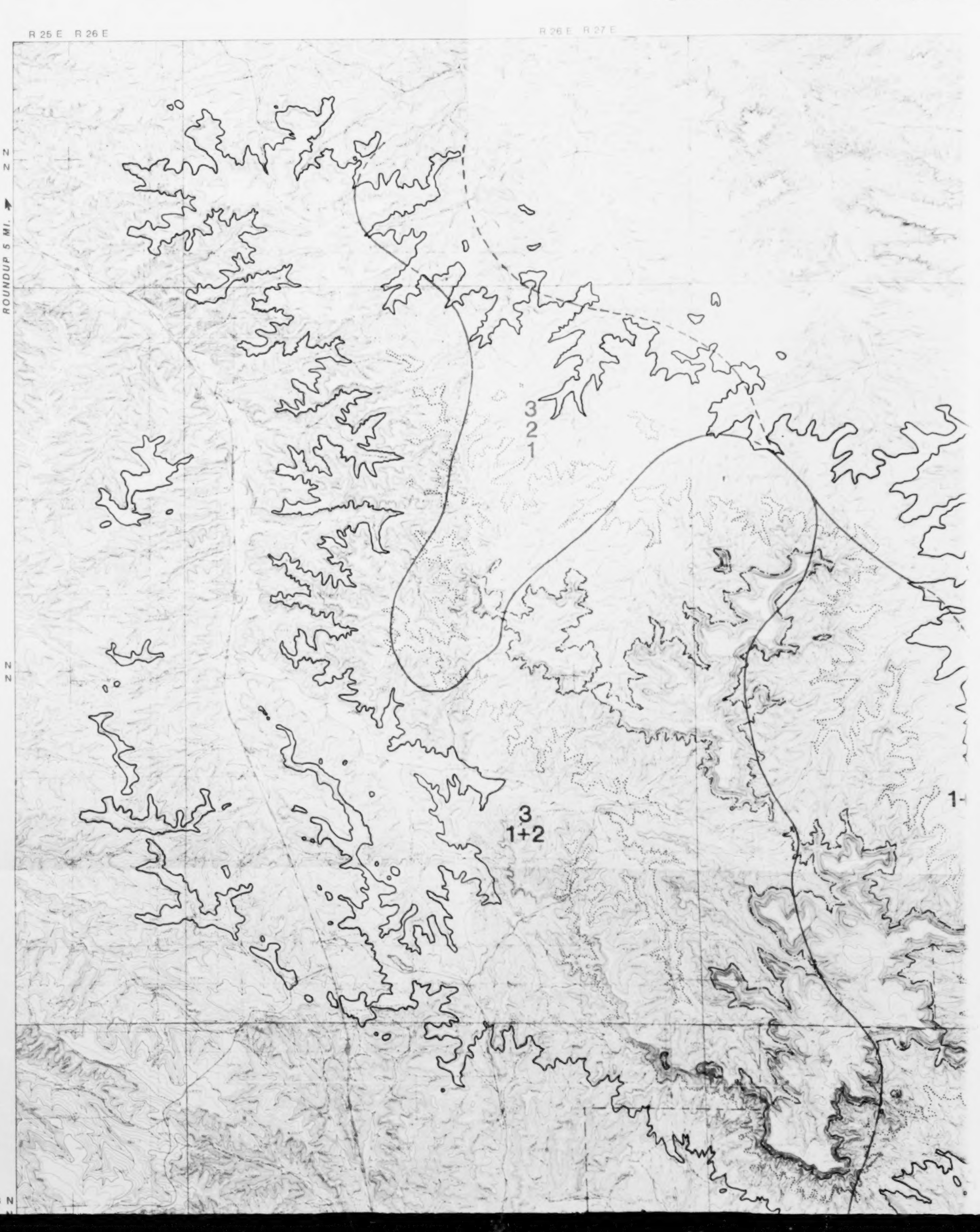


Figure 4.—Outcrop and locality map, Mam



SCALE 1:50 000

1 ½ 0 1 2 3 MILES

1 .5 0 1 2 3 KILOMETERS

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

ISOPACHS OF COAL SPLITS, COAL RESOURCES, AND COAL QUALITY

COAL INVESTIGATIONS
MAP C-126-B (SHEET 1 OF 2)

ns of short tons

one have only two significant figures. Leaders (—), no coal in this category]

		INFERRED RESOURCES													
		Thickness (ft) 2.5–5				>5–10				>10–20					
		Overburden (ft)				Overburden (ft)				Overburden (ft)					
Total	TOTAL	0–200	>200–500	>500	Total	0–200	>200–500	>500	Total	0–200	>200–500	>500	Total	TOTAL	TOTAL
0	1.16	—	—	—	0	—	—	—	0	—	—	—	0	0	0.62
0	0.53	—	—	—	0	—	—	—	0	—	—	—	0	0	1.00
0	12.9	5.23	8.39	0.18	13.8	—	—	—	0	—	—	—	0	13.8	38.3
0	19.2	8.57	0.06	—	8.63	1.37	—	—	1.37	—	—	—	0	10.0	37.8
0	11.1	2.83	—	—	2.83	0.07	—	—	0.07	—	—	—	0	2.90	28.3
0	5.80	7.26	3.27	0.01	10.5	6.77	0.73	—	7.50	—	—	—	0	18.0	25.0
0	0	0.11	—	—	0.11	—	—	—	0	—	—	—	0	0.11	0.11
0	**²49.8**	**24.1**	**11.7**	**0.19**	**36.0**	**8.21**	**0.73**	**0**	**8.94**	**0**	**0**	**0**	**0**	**44.9**	**121**
0	18.3	1.90	0.39	—	2.29	—	—	—	0	—	—	—	0	2.29	23.2
0	3.01	—	—	—	0	—	—	—	0	—	—	—	0	0	7.59
0	**21.3**	**1.90**	**0.39**	**0**	**2.29**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2.29**	**30.8**
0	4.10	1.57	—	—	1.57	—	—	—	0	—	—	—	0	1.57	11.3
0	3.76	—	—	—	0	—	—	—	0	—	—	—	0	0	16.9
0	5.81	2.17	0.34	—	2.51	—	—	—	0	—	—	—	0	2.51	11.9
0	0.09	0.30	—	—	0.30	—	—	—	0	—	—	—	0	0.30	0.81
0	0	0.08	—	—	0.08	—	—	—	0	—	—	—	0	0.08	0.08
0	**13.8**	**4.12**	**0.34**	**0**	**4.46**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4.46**	**41.1**
0	0.64	0.15	—	—	0.15	—	—	—	0	—	—	—	0	0.15	0.87
0	2.39	0.80	0.31	0.58	1.69	—	—	—	0	—	—	—	0	1.69	4.33
0	**3.03**	**0.95**	**0.31**	**0.58**	**1.84**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1.84**	**5.20**
0	**16.8**	**5.07**	**0.65**	**0.58**	**6.30**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6.30**	**48.2**
0.07	36.0	—	—	—	0	9.08	—	—	9.08	—	—	—	0	9.08	³89.0
12.7	46.4	—	—	—	0	—	0.03	0.84	0.87	—	0.03	3.36	3.39	4.26	121
2.69	56.3	—	—	—	0	29.1	0.05	0.08	29.2	—	—	—	0	29.2	⁴105
33.9	45.4	—	—	—	0	—	2.50	1.14	3.64	0.31	6.69	3.53	10.5	14.1	71.3
0	0	—	—	—	0	5.23	—	—	5.23	—	—	—	0	5.23	5.23
49.3	**184**	**0**	**0**	**0**	**0**	**43.4**	**2.58**	**2.04**	**48.0**	**0.31**	**6.72**	**6.89**	**13.9**	**61.9**	**⁵382**
2.16	2.16	—	—	—	0	—	—	—	0	—	—	—	0	0	3.76
11.7	22.8	—	—	—	0	—	—	0.50	0.50	0.14	3.57	6.48	10.2	10.7	38.9
13.9	**25.0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.50**	**0.50**	**0.14**	**3.57**	**6.48**	**10.2**	**10.7**	**42.7**
63.2	**209**	**0**	**0**	**0**	**0**	**43.4**	**2.58**	**2.54**	**48.5**	**0.45**	**10.3**	**13.4**	**24.1**	**72.6**	**⁵434**
0	0.77	—	—	—	0	—	—	—	0	—	—	—	0	0	1.24
0	23.9	—	—	—	0	11.5	13.4	0.31	25.2	—	—	—	0	25.2	53.2
0	0.05	0.02	—	—	0.02	—	—	—	0	—	—	—	0	0.02	0.25
0	7.47	0.12	—	—	0.12	2.57	—	—	2.57	—	—	—	0	2.69	15.7
0	14.9	—	—	—	0	14.6	5.08	0.03	19.7	—	—	—	0	19.7	38.1
0	**47.1**	**0.14**	**0**	**0**	**0.14**	**28.7**	**18.5**	**0.34**	**47.5**	**0**	**0**	**0**	**0**	**47.6**	**108**
87.9	87.9	—	—	—	0	—	—	—	0	—	0.46	—	0.46	0.46	171
34.0	34.0	—	—	—	0	—	—	—	0	1.45	5.30	—	6.75	6.75	52.8
23.4	23.4	—	—	—	0	—	—	—	0	—	—	—	0	0	40.1
145	**145**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1.45**	**5.76**	**0**	**7.21**	**7.21**	**263**
0	0	—	—	—	0	—	—	—	0	—	—	—	0	0	1.82
56.4	56.4	—	—	—	0	—	—	—	0	1.77	0.05	—	1.82	1.82	80.6
5.87	5.87	—	—	—	0	—	—	—	0	—	—	—	0	0	10.7
62.3	**62.3**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1.77**	**0.05**	**0**	**1.82**	**1.82**	**93.2**
208	**208**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3.22**	**5.81**	**0**	**9.03**	**9.03**	**357**
271	¹561	31.2	12.7	0.77	44.7	80.3	21.8	2.89	105	3.67	18.1	13.4	33.1	183	1,100

B.—Calculated according to kriging method (table adapted from Pierce and others, 1983)

RESOURCES (95 percent confidence interval may be computed using number in parentheses) Thickness (ft) 2.5–5	>5–10	>10–20	TOTAL
—	—	—	0
—	1.04 (±0.18)	—	1.04
15.3 (±0.77)	17.1 (±0.86)	—	32.4
—	43.6 (±1.74)	—	43.6
4.28 (±0.17)	24.2 (±0.97)	—	28.5
19.1 (±2.10)	1.62 (±0.16)	—	20.7
—	0.26 (±0.08)	—	0.26
38.7	**87.8**	**0**	**126**
17.0 (±2.71)	5.12 (±0.82)	—	22.1
9.66 (±1.29)	—	—	9.66
26.7	**5.12**	**0**	**¹32.0**
28.7 (±2.87)	1.71 (±0.17)	—	30.4
23.4 (±1.17)	—	—	23.4
7.18 (±1.38)	—	—	7.18
—	—	—	0
—	—	—	0
59.3	**1.71**	**0**	**61.0**
0.94 (±0.40)	—	—	0.94
5.69 (±1.94)	—	—	5.69
6.63	**0**	**0**	**6.63**
65.9	**1.71**	**0**	**67.6**
—	90.1 (±1.80)	—	90.1
—	105 (±1.06)	17.0 (±0.17)	122
4.23 (±0.08)	87.5 (±1.75)	—	91.7
—	48.2 (±0.96)	17.6 (±0.35)	65.8
1.39 (±0.46)	0.44 (±0.14)	—	1.83
5.62	**332**	**34.6**	**372**
—	3.14 (>±2.82)	—	3.14
—	15.3 (±0.61)	22.6 (±0.90)	37.9
0	**18.4**	**22.6**	**41.0**
5.62	**350**	**57.2**	**413**
—	1.41 (>±1.27)	—	1.41
—	54.0 (±4.32)	—	54.0
0.36 (>±0.32)	—	—	0.36
0.56 (±0.07)	16.4 (±1.97)	—	17.0
—	31.3 (±4.07)	16.6 (±2.16)	47.9
0.92	**103**	**16.6**	**121**
—	—	173 (±0.86)	173
—	—	52.5 (±0.52)	52.5
—	—	41.0 (±0.41)	41.0
0	**0**	**267**	**267**
—	—	2.74 (±0.66)	2.74
—	—	84.4 (±0.84)	84.4
—	—	11.2 (±0.34)	11.2
0	**0**	**98.3**	**98.3**
0	**0**	**385**	**385**
138	548	430	1,120

¹Includes resources for T. 8 N., R. 26 E.: 0.21 million short tons for thickness of >5–10 ft

Table 3.—Major- and minor-oxide and trace-element compositions of the laboratory ash of eight coal samples from the Mammoth coal, compared with Powder River region coal samples

[Coals were ashed at 525°C. L, less than value shown; N, not detected; leaders (---), not determined. -S, values listed were determined by semiquantitative spectrographic analysis. Spectrographic results for samples D189148–D189151 are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are reported arbitrarily as midpoints of those brackets: 1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. Precision of spectrographic data is approximately one bracket at 68-percent confidence, or two brackets at 95-percent confidence; confidence of values for samples D221596–D221599 ranges between plus 50 percent and minus 33 percent]

	Sample No.	Ash (percent)	SiO₂ (percent)	Al₂O₃ (percent)	CaO (percent)	MgO (percent)	Na₂O (percent)	K₂O (percent)	Fe₂O₃ (percent)	TiO₂ (percent)	SO₃ (percent)	Ag-S ppm	B-S ppm	Ba-S ppm	Be-S ppm	Cd ppm	Ce-S ppm	Cu ppm	Ga-S ppm	Ge-S ppm	La-S ppm	Li ppm	Mn ppm	Mo-S ppm	Nb-S ppm	Ni-S ppm	Pb ppm	Sc-S ppm	Sr-S ppm	V-S ppm	Y-S ppm	Yb-S ppm	Zn ppm	Zr-S ppm
+2																																		
ft	D189151	8.4	32	20	11	1.9	0.23	0.27	8.6	1.0	12	N	500	5,000	5	1.0	N	95	20	N	N	150	380	10	N	30	35	15	2,000	70	50	5	180	200
ft	D189150	7.1	34	22	7.7	2.7	.28	.35	11	.97	11	N	500	5,000	7	1.0L	N	93	30	N	N	130	510	10	N	15	50	10	1,500	70	50	5	75	150
+2																																		
4 ft	D189149	10.5	29	17	23	1.7	0.16	0.23	7.3	0.85	8.7	N	200	3,000	N	1.0L	N	92	20	N	N	87	820	10	N	15	45	10	1,500	70	50	5	78	150
ft	D189148	6.8	24	16	14	2.4	.18	.29	17	.83	12	N	500	7,000	10	1.0L	N	78	30	20	70	70	420	20	N	10	40	20	2,000	70	70	7	44	150
+2+3																																		
7 ft	D221596	8.9	41	25	6.0	1.2	2.8	0.37	7.3	0.94	---	0.92L	300	5,100	5.7	1.0L	170	88	42	7.4	67	130	370	12	82	27	42	18	2,700	120	62	5.2	120	1,100
3 ft	D221597	9.8	45	28	4.9	1.0	2.4	.42	4.6	.90	---	.92L	340	3,200	8.9	1.0L	190	95	43	12	85	160	330	7.6	62	31	51	21	2,400	160	90	6.1	61	990
+2+3																																		
9 ft	D221598	9.2	41	21	5.5	1.5	2.8	0.79	9.0	1.2	---	0.97	350	2,800	6.9	2.0	160	77	36	6.7	64	110	370	16	43	27	25L	15	2,800	150	56	4.9	59	720
4 ft	D221599	12.1	45	28	4.1	.83	1.9	.41	4.9	.92	---	.92L	340	5,700	8.2	1.0L	180	88	57	11	69	130	240	9.1	57	28	48	19	2,100	170	67	5.5	92	750
n Mammoth		8.9	36	22	9.5	1.7	1.3	0.40	9.0	0.96	11.4	0.93L	390	4,800	7.7L	1.0L	170L	88	34	13L	71L	120	400	12	96L	22	41L	16	2,200	110	62	5.4	85	520
n 410 Powder al samples		9.9	30	14	18	4.0	1.8	0.50	7.3	0.68	17	---	---	---	---	0.8	---	123	---	---	---	56	---	---	---	---	68	---	---	---	---	---	208	---

g weighted average for each locality

d Swanson (1977, table 6A). "Powder River region" of Hatch and Swanson is from Trumbull (1960), and is approximately equivalent to the Powder River basin

4.—Content of 40 elements in eight coal samples from the Mammoth coal, reported on whole-coal basis, compared with Powder River region coal samples

[As, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) coal; remaining analyses calculated from determinations on ash. -S, content determined by semiquantitative spectrographic analysis (see table 3). L, less than value shown; N, not detected; leaders (---), not determined]

mple No.	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	Ag-S ppm	As ppm	B-S ppm	Ba-S ppm	Be-S ppm	Cd ppm	Ce-S ppm	Co ppm	Cr ppm	Cu ppm	F ppm	Ga-S ppm	Ge-S ppm	Hg ppm	La-S ppm	Li ppm	Mn ppm	Mo-S ppm	Nb-S ppm	Ni-S ppm	Pb ppm	Sb ppm	Sc-S ppm	Se ppm	Sr-S ppm	Th ppm	U ppm	V-S ppm	Y-S ppm	Yb-S ppm	Zn ppm	Zr-S ppm
89151	1.3	0.89	0.86	0.094	0.014	0.019	0.50	0.050	N	2.2	50	500	0.5	0.084	N	1.8	2.9	8.0	35	1.5	N	0.11	N	13	32	1	N	2	2.9	0.40	1.5	0.10L	150	1.5	1.2	7	5	0.5	13	15
89150	1.1	.83	.39	.11	.015	.021	.56	.041	N	1.3	30	300	.5	.071L	N	1.3	2.5	6.6	20L	2	N	.04	N	9.4	38	.7	N	1	3.6	.43	.7	.40	100	1.5	1.1	5	3	.3	5.3	10
89149	1.4	0.94	1.7	0.10	0.012	0.020	0.54	0.053	N	3.8	20	300	N	0.11L	N	1.1	3.3	9.7	20	2	N	0.11	N	9.1	65	1	N	1.5	4.7	0.40	1	0.52	150	1.5	1.7	7	5	0.5	8.0	15
89148	.74	.56	.86	.096	.008	.016	.78	.033	N	3.1	30	500	.7	.080L	N	1.2	2.5	5.1	20L	2	1.5	.07	5	4.6	28	1.5	N	.7	2.8	1.3	1.5	.25	150	1.2	1.4	5	5	.5	2.9	10
21596	1.7	1.2	0.38	0.064	0.17	0.027	0.45	0.050	0.082L	1.8	27	460	0.51	0.089L	15	0.76	2.9	7.7	20	3.7	0.66	0.12	6.0	12	33	1.1	5.5	2.4	3.7	0.67	1.4	0.98	240	1.9	1.4	11	5.5	0.46	10	98
21597	2.0	1.4	.34	.058	.17	.034	.31	.052	.088L	2.0	33	310	.85	.086L	18	1.1	3.8	9.1	20	4.1	1.2	.07	8.2	15	31	.73	6.0	3.0	4.5	.94	2.0	.74	230	2.2	1.4	15	8.8	.59	5.9	95
21598	1.7	1.0	0.36	0.081	0.18	0.061	0.58	0.084	0.089	2.1	32	240	0.63	0.18	15	0.75	2.6	7.1	25	3.3	0.62	0.07	5.9	10	34	1.5	4.0	2.5	2.3L	0.46	1.4	0.54	240	1.1	1.2	14	5.1	0.45	5.4	66
21599	2.5	1.8	.35	.060	.17	.041	.41	.087	.11L	1.0	41	690	.99	.12L	22	.97	3.7	11	25	6.9	1.3	.06	8.3	16	29	1.1	6.9	3.1	5.8	1.2	2.3	---	250	2.5	1.4	21	8.1	.67	11	91
	1.5	1.1	0.86	0.083	0.094	0.030	0.52	0.051	0.098L	2.2	33	410	0.67L	0.10L	17L	1.1	3.0	7.9	23L	3.2	1.1L	0.08	8.4L	11	35	1.1	5.5L	2.1	3.7L	0.74	1.5	0.50L	180	1.6	1.3	10	5.6	0.49	7.5	50
	1.5	0.78	1.1	0.21	0.11	0.048	0.54	0.041	---	3	70	300	0.7	0.09	---	2	7	11.2	46	3	---	0.11	---	5.9	51	2	15	5	8.4	0.6	2	1.0	200	4.3	0.9	15	5	0.5	20	15

average for each locality

1977, table 6A). "Powder River region" of Hatch and Swanson is from Trumbull (1960), and is approximately equivalent to the Powder River basin

ft of overburden; 372 million den, and 120 million short tons verburden is about 800 ft in the verburden closures.

rces is T. 6 N., R. 27 E., with 435 rge resources, 140–180 million 26 E., and T. 7 N., R. 27 E. The mmoth coal bed each have less

mining should be considered overlain by channel and splay noth 3. Horne and others (1977, "where splay deposits occur 20 ft (6 m) thick, and have a rider e top of the splay, severe roof ining." About half of Mammoth ay be delineated by overlaying sopach of the channel and splay is series.

THICKNESS OF COAL BEDS IN FEET
THICKNESS
765+–845 feet
890–1,210 feet
lember (part)

Mammoth coal bed and other he Bull Mountain coal field. (1917).

COAL QUALITY

Based on analyses of 11 samples at six localities (table 2), the Mammoth coal contains an average (arithmetic mean) of 31.8 percent volatile matter, 7.1 percent ash, and 0.8 percent sulfur, about half of which is pyritic and half organic. Its apparent rank is subbituminous A to high-volatile C bituminous, as the heat of combustion on an as-received, moist, mineral-matter-free basis ranges from 10,580 to 12,080 Btu/lb and averages 11,260 Btu/lb. Vitrinite reflectance values of 0.4–0.5 percent (Daniel, 1982) on coal samples from the same localities as the first four localities listed on table 2 indicate the same range in apparent rank reported here. The relationship of vitrinite reflectance to coalification stages is discussed in Davis (1978) and summarized on table 4 of that publication.

The Mammoth coal of the Bull Mountain basin is of higher quality than Powder River basin coals deposited at about the same time, before the individual basins formed. Mammoth coal is of higher apparent rank (Powder River region coals are, on the average, subbituminous C), and the sulfur content is about half that of the Powder River region coal (table 2, last row). Furthermore, trace-element analyses of eight Mammoth coal samples from four localities (tables 3 and 4), when compared with Powder River region coal samples (last row, both tables), show that the Mammoth samples have about half as much of the commonly considered potentially toxic B, F, Mo, Pb, and Se. Toxicity hazards from environmental concentrations of these elements are discussed in Gough and others (1979). There may be fewer such hazards with the Mammoth coal than with the Powder River region coals. Only two elements occur in the Mammoth samples in considerably greater concentration than in the Powder River region (in fact, they are three to four times more abundant): Nb and Zr. The larger amounts of these elements, probably held in the heavy minerals, may be due to the Mammoth coal bed area having been closer to early Tertiary sources of volcanic ash than the Powder River area. Nb and Zr are unlikely environmental hazards.

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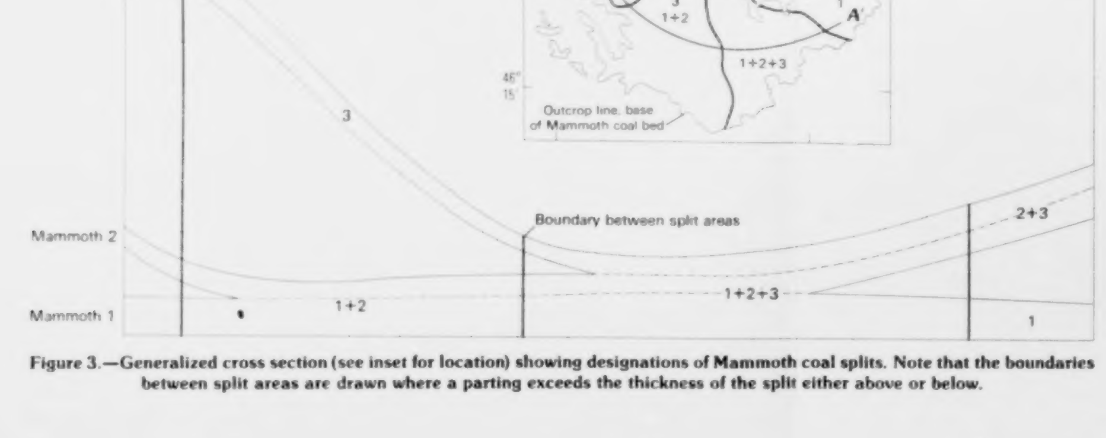
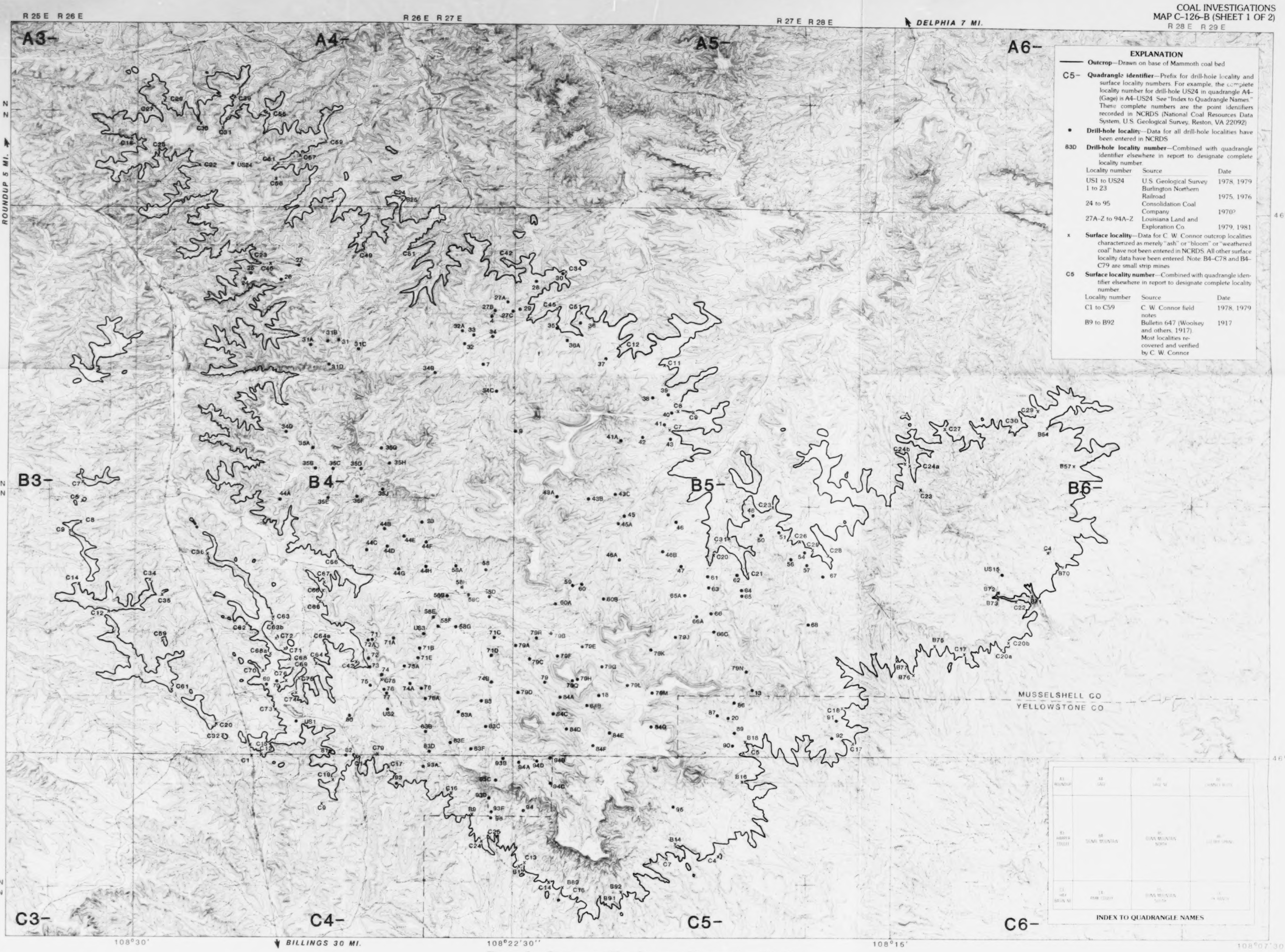


Figure 3.—Generalized cross section (see inset for location) showing designations of Mammoth coal splits. Note that the boundaries between split areas are drawn where a parting exceeds the thickness of the split either above or below.

1:50 000
1 2 3 MILES
1 2 3 KILOMETERS
NTERVAL 20 FEET
VERTICAL DATUM OF 1929

COAL SPLITS, COAL RESOURCES, AND COAL QUALITY—
ER MEMBER OF THE FORT UNION FORMATION.



EXPLANATION

Outcrop—Drawn on base of Mammoth coal bed

C5– **Quadrangle identifier**—Prefix for drill-hole locality and surface locality numbers. For example, the complete locality number for drill-hole US24 in quadrangle A4–(Gage) is A4–US24. See "Index to Quadrangle Names." These complete numbers are the point identifiers recorded in NCRDS (National Coal Resources Data System, U.S. Geological Survey, Reston, VA 22092)

● **Drill-hole locality**—Data for all drill-hole localities have been entered in NCRDS

83D **Drill-hole locality number**—Combined with quadrangle identifier elsewhere in report to designate complete locality number

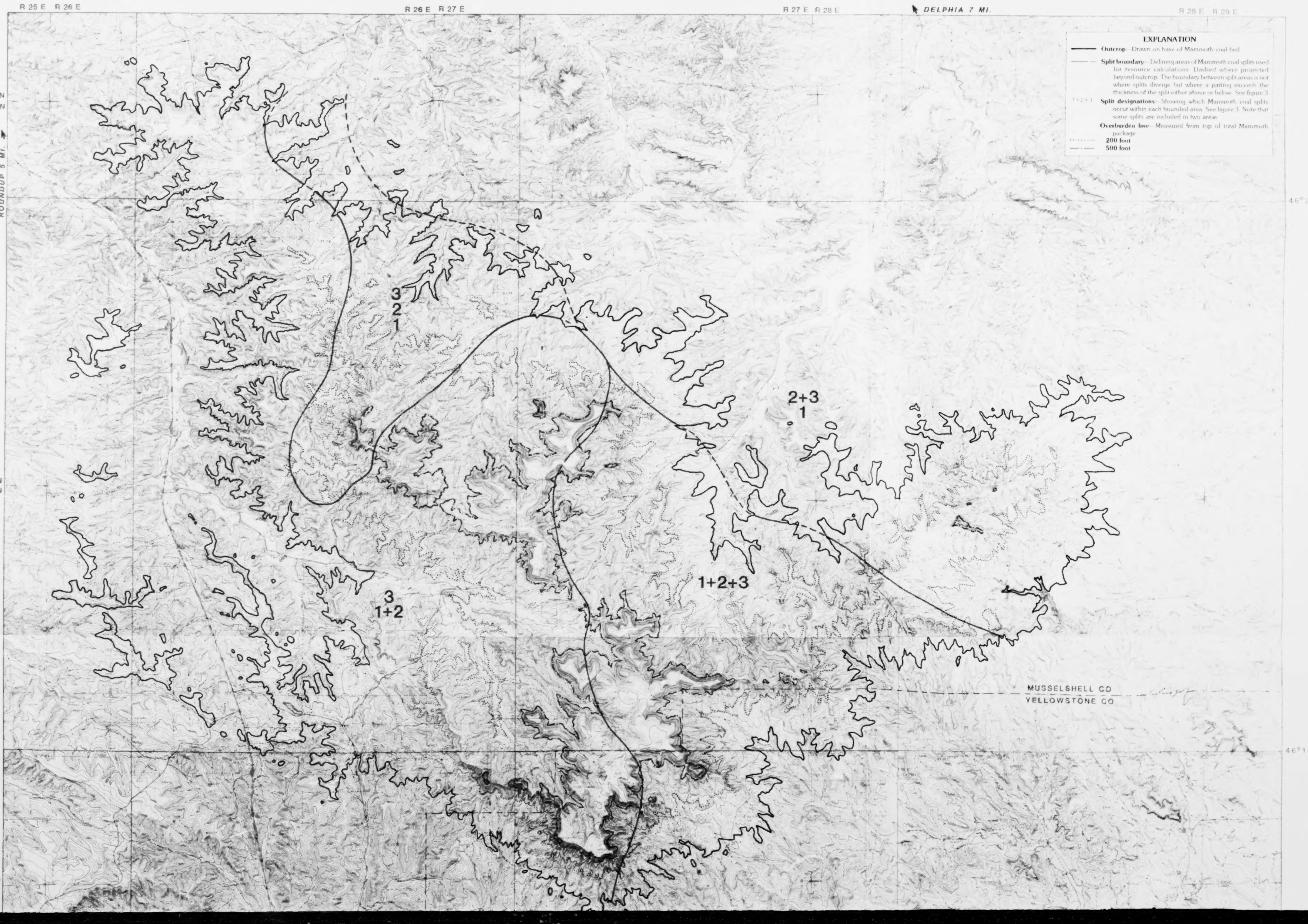
Locality number	Source	Date
US1 to US24	U.S. Geological Survey	1978, 1979
1 to 23	Burlington Northern Railroad	1975, 1976
24 to 95	Consolidation Coal Company	1970?
27A–Z to 94A–Z	Louisiana Land and Exploration Co.	1979, 1981

x **Surface locality**—Data for C. W. Connor outcrop localities characterized as merely "ash" or "bloom" or "weathered coal" have not been entered in NCRDS. All other surface locality data have been entered. Note: B4–C78 and B4–C79 are small strip mines

C6 **Surface locality number**—Combined with quadrangle identifier elsewhere in report to designate complete locality number

Locality number	Source	Date
C1 to C59	C. W. Connor field notes	1978, 1979
B9 to B92	Bulletin 647 (Woolsey and others, 1917). Most localities recovered and verified by C. W. Connor	1917

Figure 4.—Outcrop and locality map, Mammoth coal bed.



EXPLANATION

Outcrop—Drawn on base of Mammoth coal bed

Split boundary—Defining areas of Mammoth coal splits used for resource calculations. Dashed where projected beyond outcrop. The boundary between split areas is not where splits diverge but where a parting exceeds the thickness of the split either above or below. See figure 3

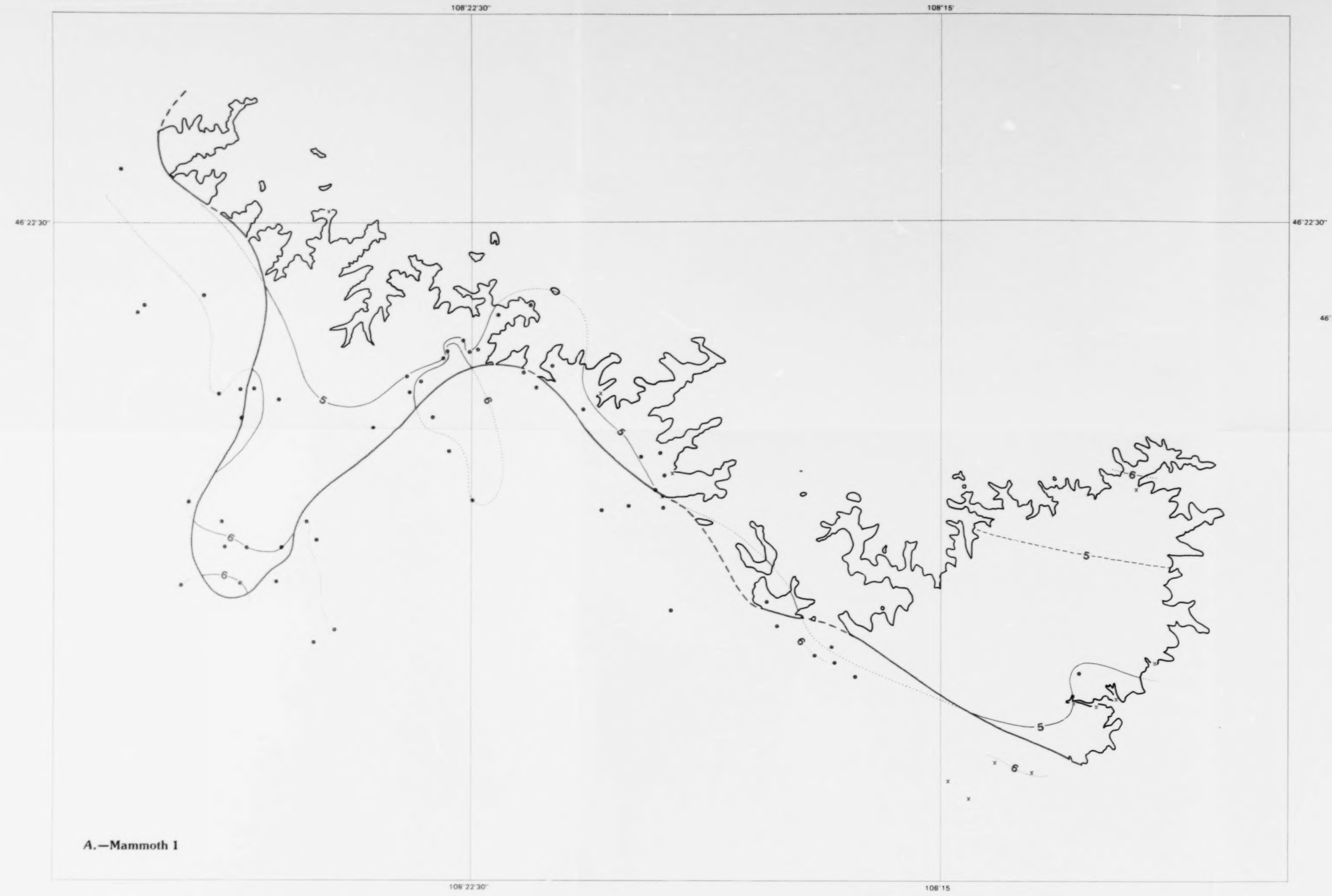
1+2+3 **Split designations**—Showing which Mammoth coal splits occur within each bounded area. See figure 3. Note that some splits are included in two areas

Overburden line—Measured from top of total Mammoth package

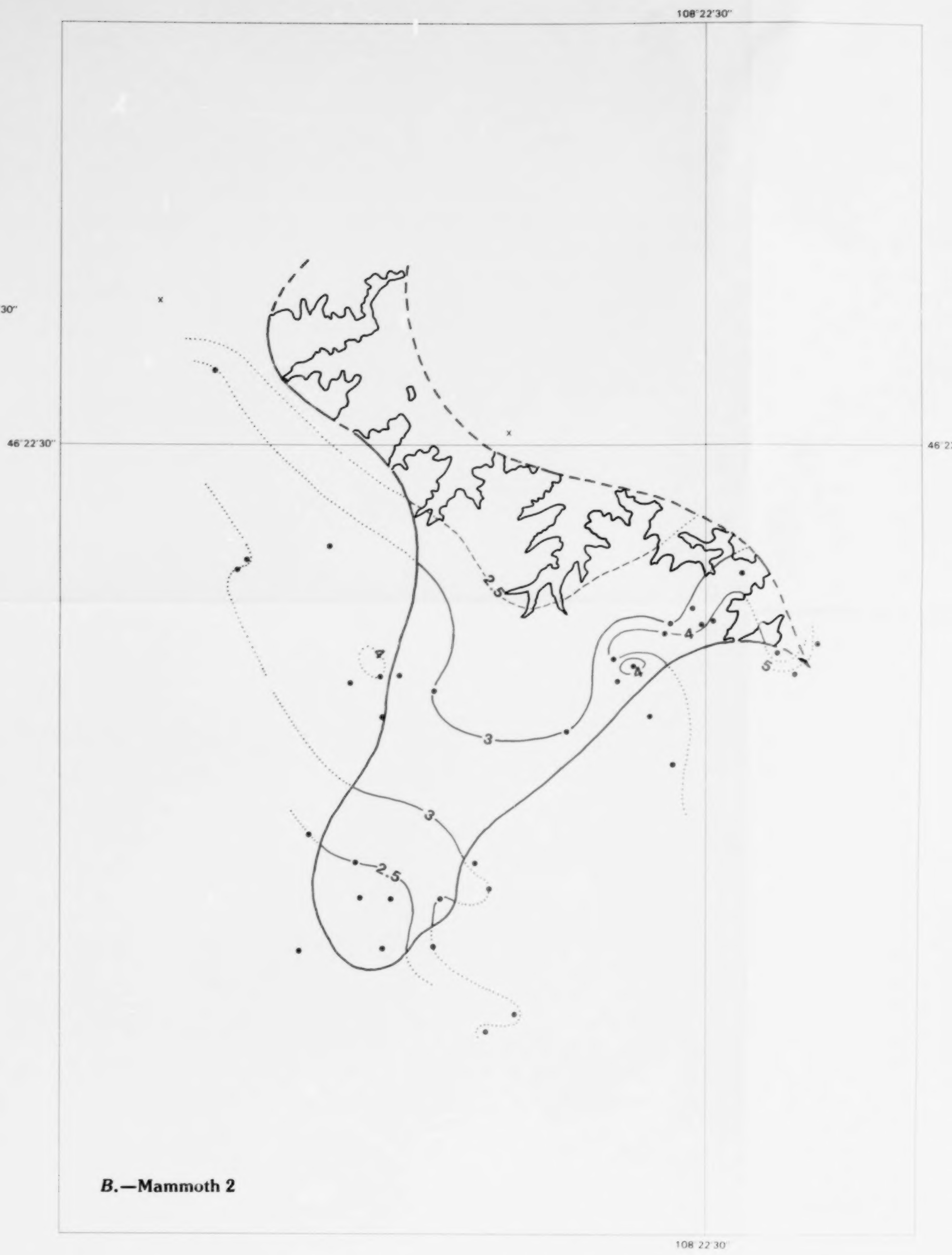
200 foot

500 foot

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY


108°22'30"
108°15'
46°22'30"
46°22'30"
5
6
5
6
6
6
5
6
5
6
108°22'30"
108°15'

A.—Mammoth 1


108°22'30"
46°22'30"
2.5
4
4
5
3
3
2.5
108°22'30"

B.—Mammoth 2

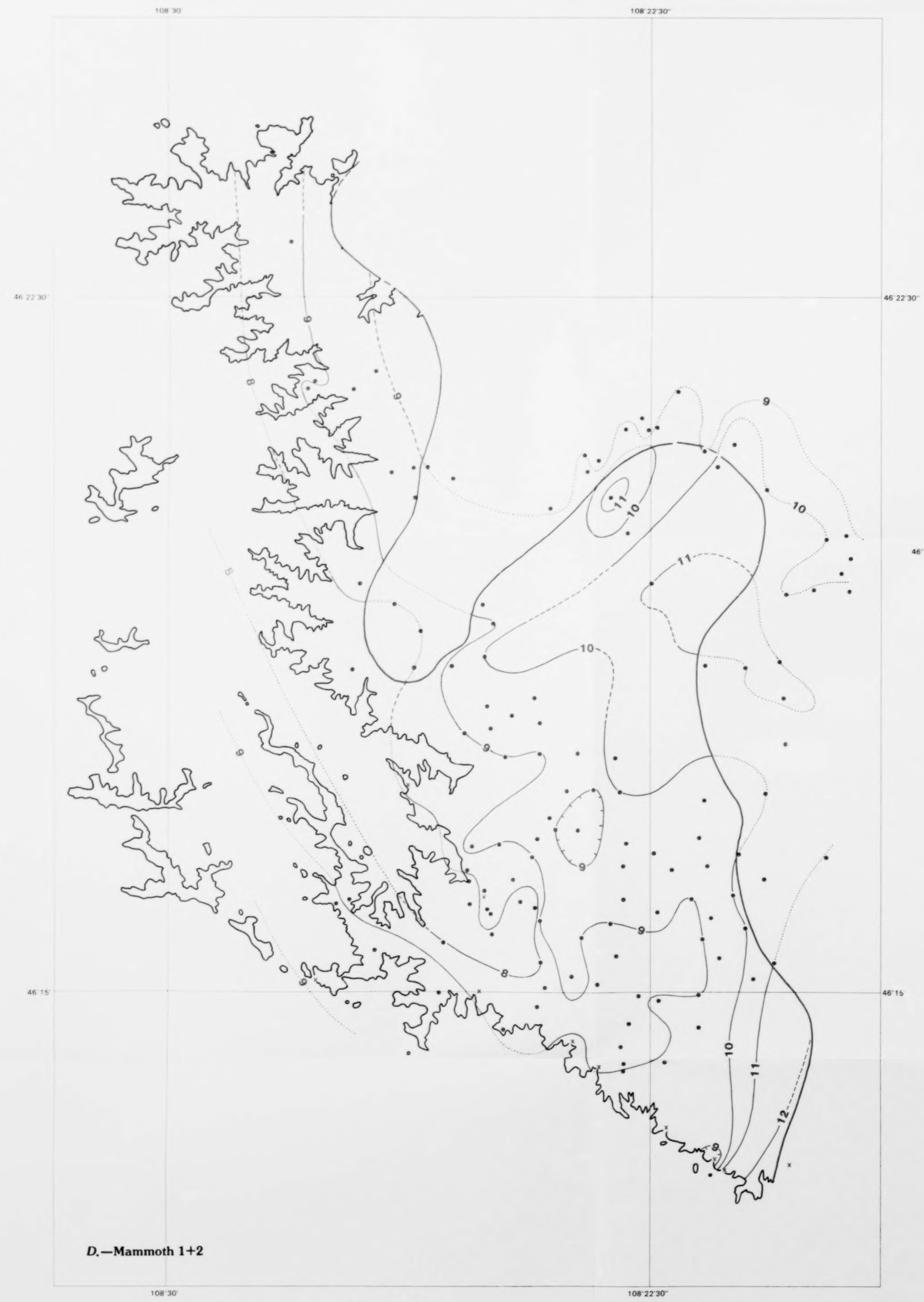
EXPLANATION

Outcrop—Drawn on base of Mammoth coal bed

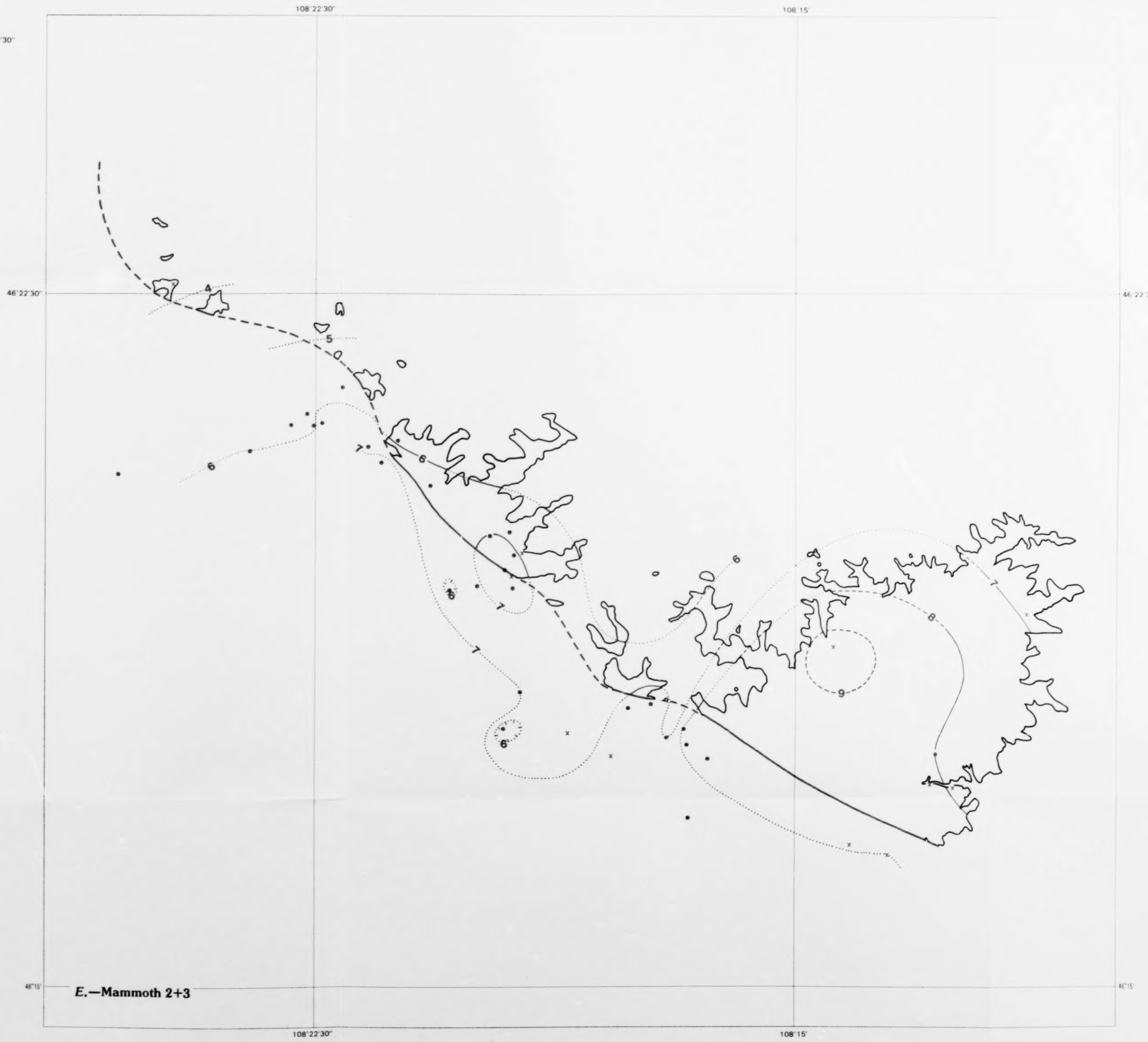
Split boundary—See figure 5

Drill-hole (•) or surface (×) locality—Only localities used in constructing each isopach map are shown on that map. Locality numbers shown on figure 4

Isopachs—Showing thickness of coal, in feet. Dashed where inferred; dotted where projected into adjacent area where split can be identified or where projected beyond outcrop


108°30'
108°22'30"
46°22'30"
46°22'30"
9
9
8
10
9
10
11
10
9
9
9
9
8
9
10
11
12
9
46°15'
46°15'
108°30'
108°22'30"

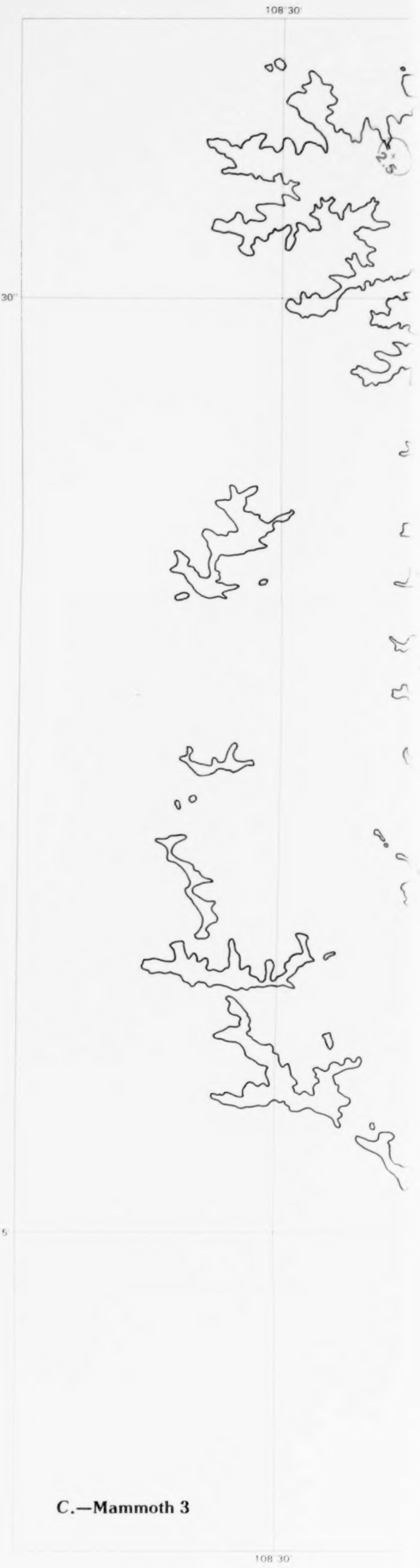
D.—Mammoth 1+2


108°22'30"
108°15'
46°22'30"
4
5
6
7
6
6
7
7
6
8
9
46°15'
46°15'
108°22'30"
108°15'

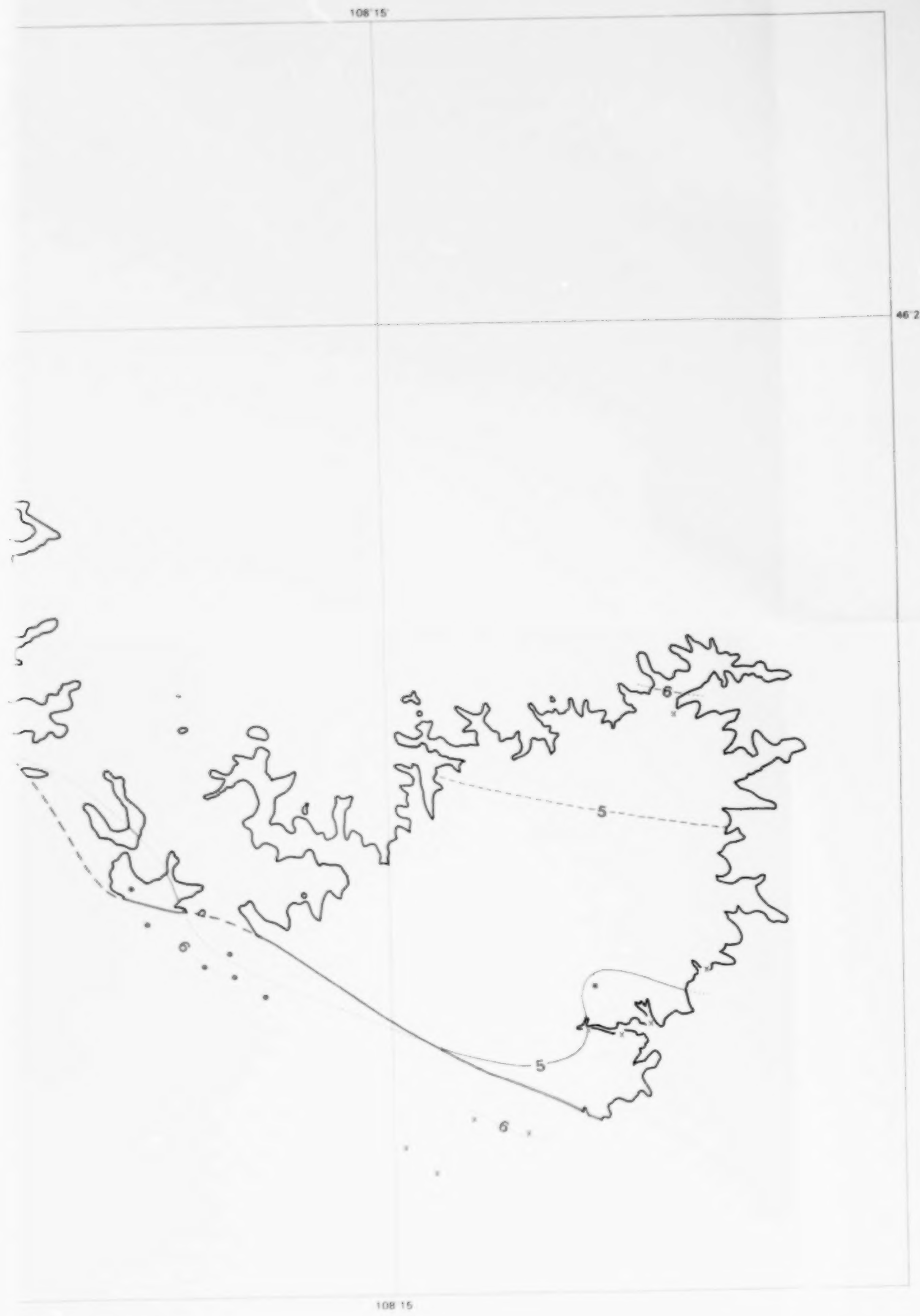
E.—Mammoth 2+3

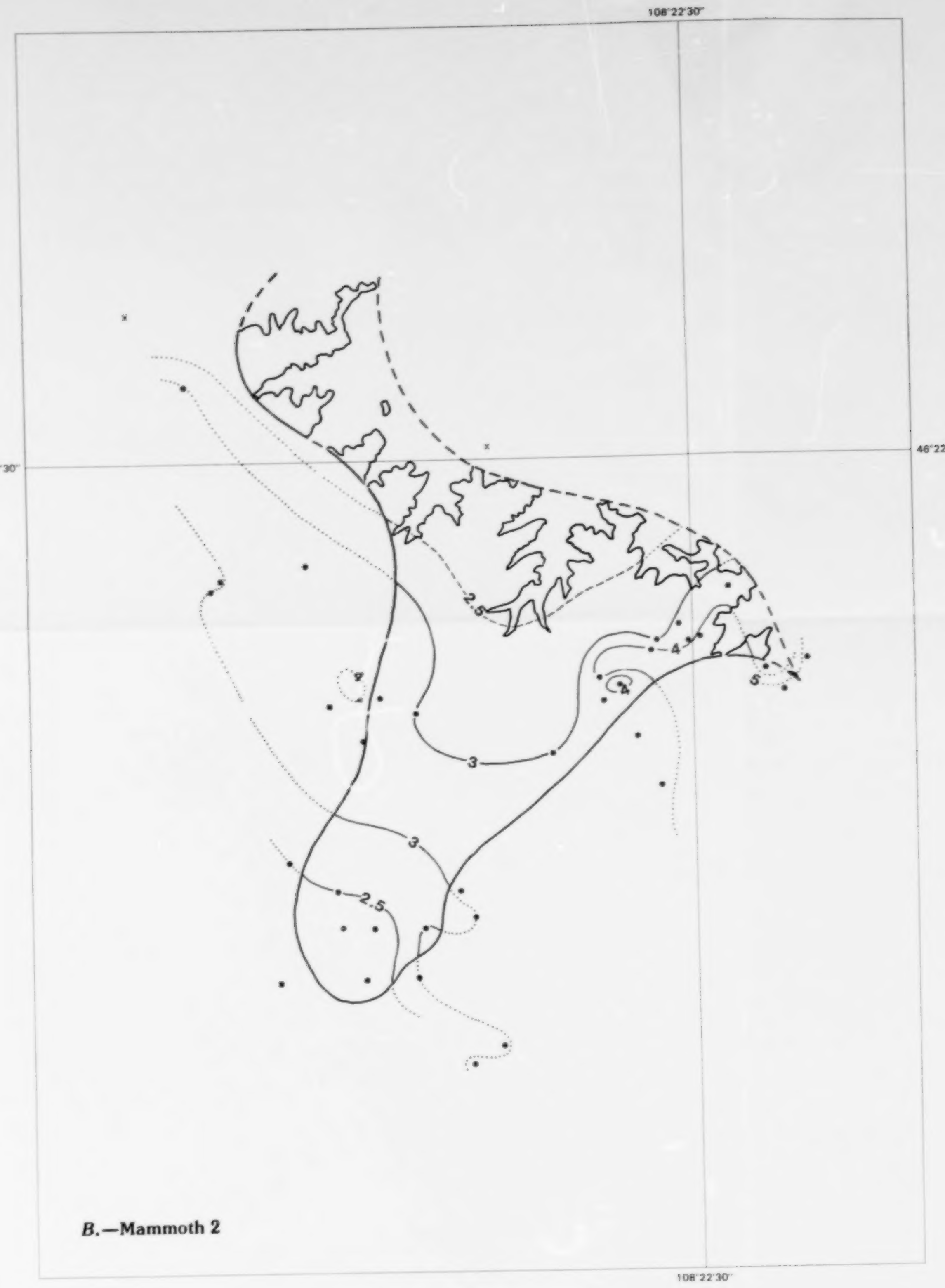
SCALE 1:50 000
1 ½ 0 1 2 3 MILES
1 .5 0 1 2 3 KILOMETERS

COAL INVESTIGATIONS
MAP C-126-B (SHEET 2 OF 2)

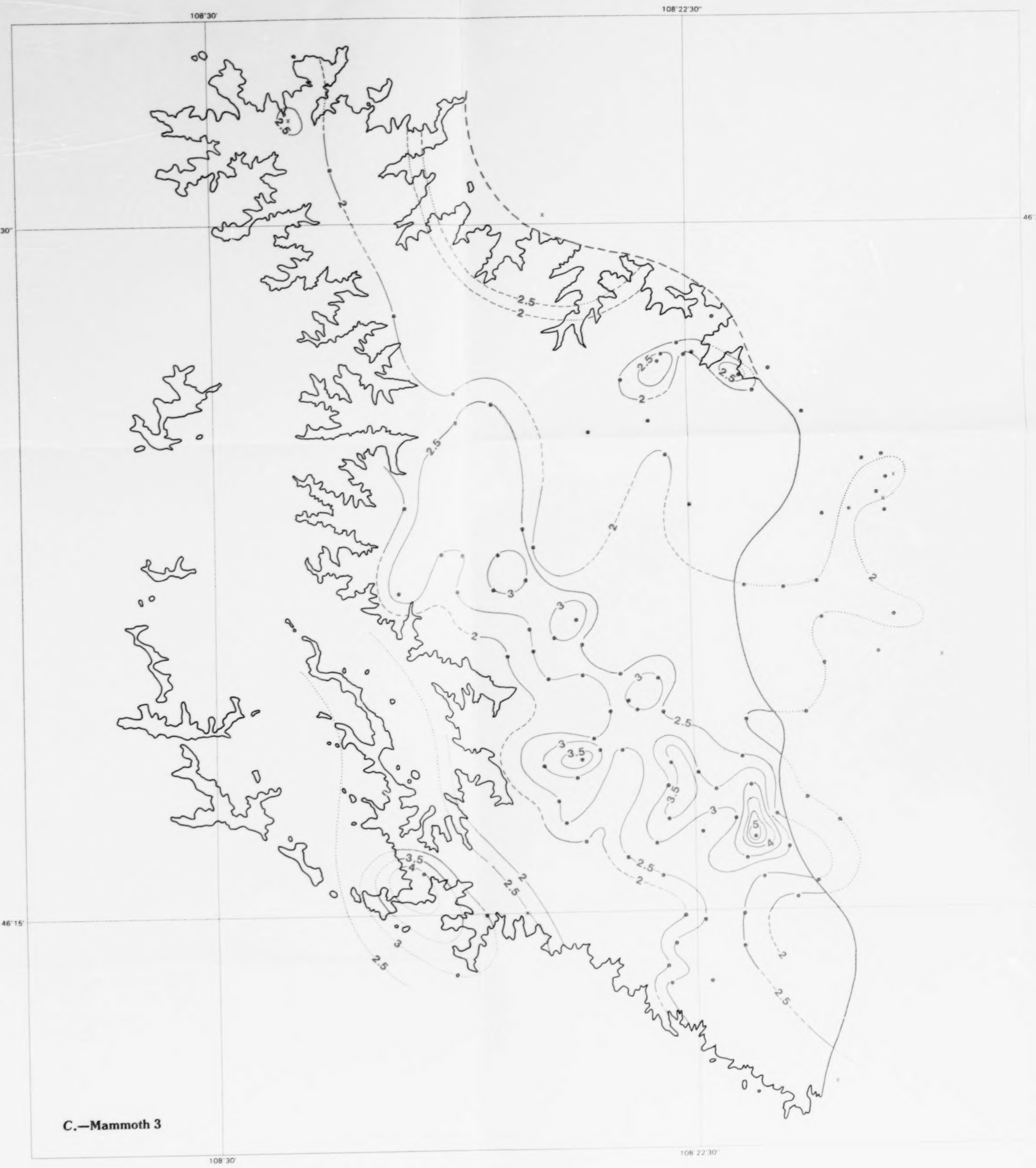

108°30'
46°22'30"
46°15'
108°30'
2.5

C.—Mammoth 3


108°15'
46°22'30"
108°15'
5
6
5
6


108°22'30"
46°22'30"
46°22'30"
108°22'30"
2
3
4
5
3
2.5

B.—Mammoth 2


108°30'
108°22'30"
46°22'30"
46°22'30"
46°15'
46°15'
108°30'
108°22'30"
2
2.5
3
3.5
4
4.5
5

C.—Mammoth 3

EXPLANATION

Outcrop—Drawn on base of Mammoth coal bed

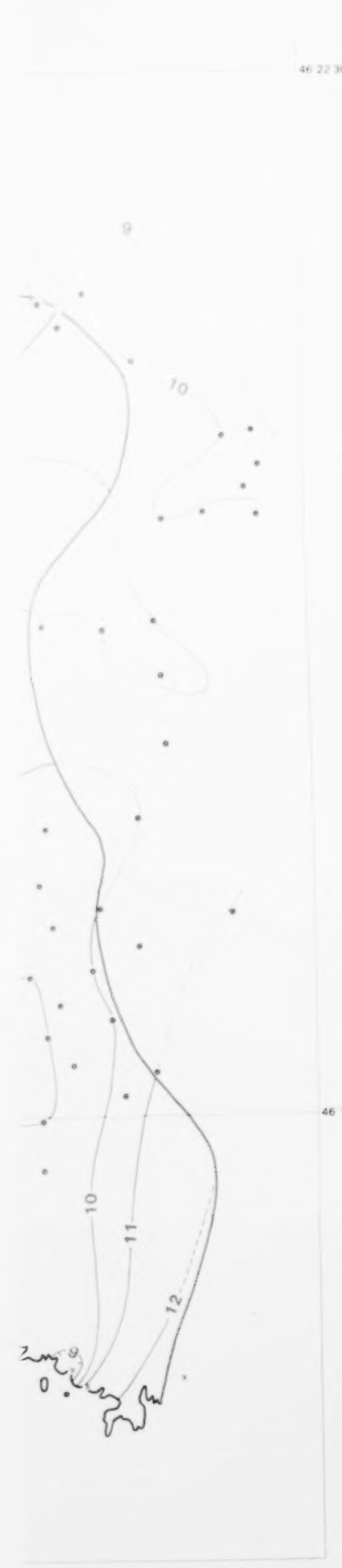
Split boundary—See figure 5

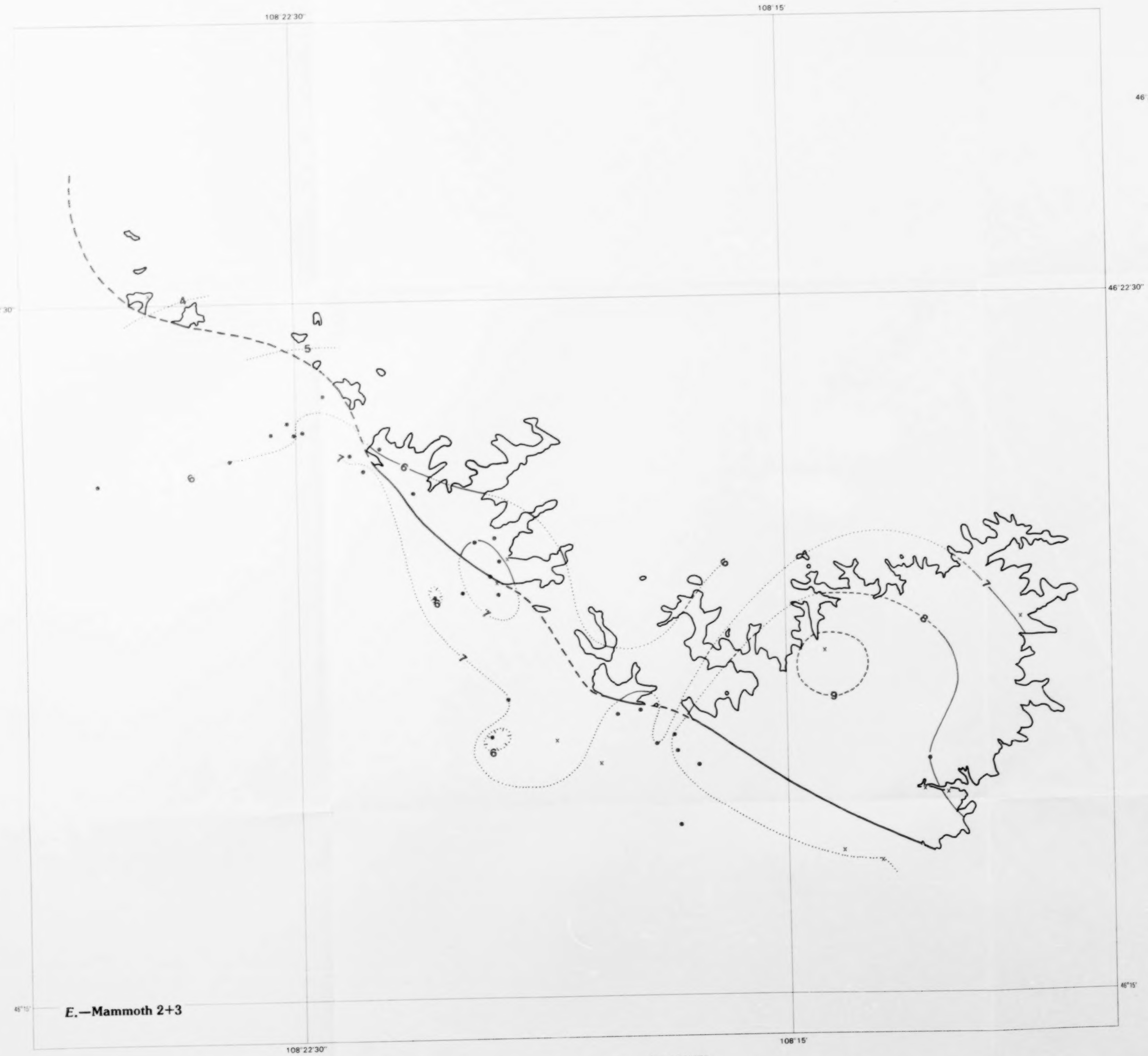
● x **Drill-hole (●) or surface (x) locality**—Only localities used in constructing each isopach map are shown on that map. Locality numbers shown on figure 4

—6— **Isopachs**—Showing thickness of coal, in feet. Dashed where inferred; dotted where projected into adjacent area where split can be identified or where projected beyond outcrop

46°22'30"
46°15'
10
11
12
11
12
12
11
13
12
11

F.—Mammoth 1+2+3


46°22'30"
46°15'
9
10
10
11
12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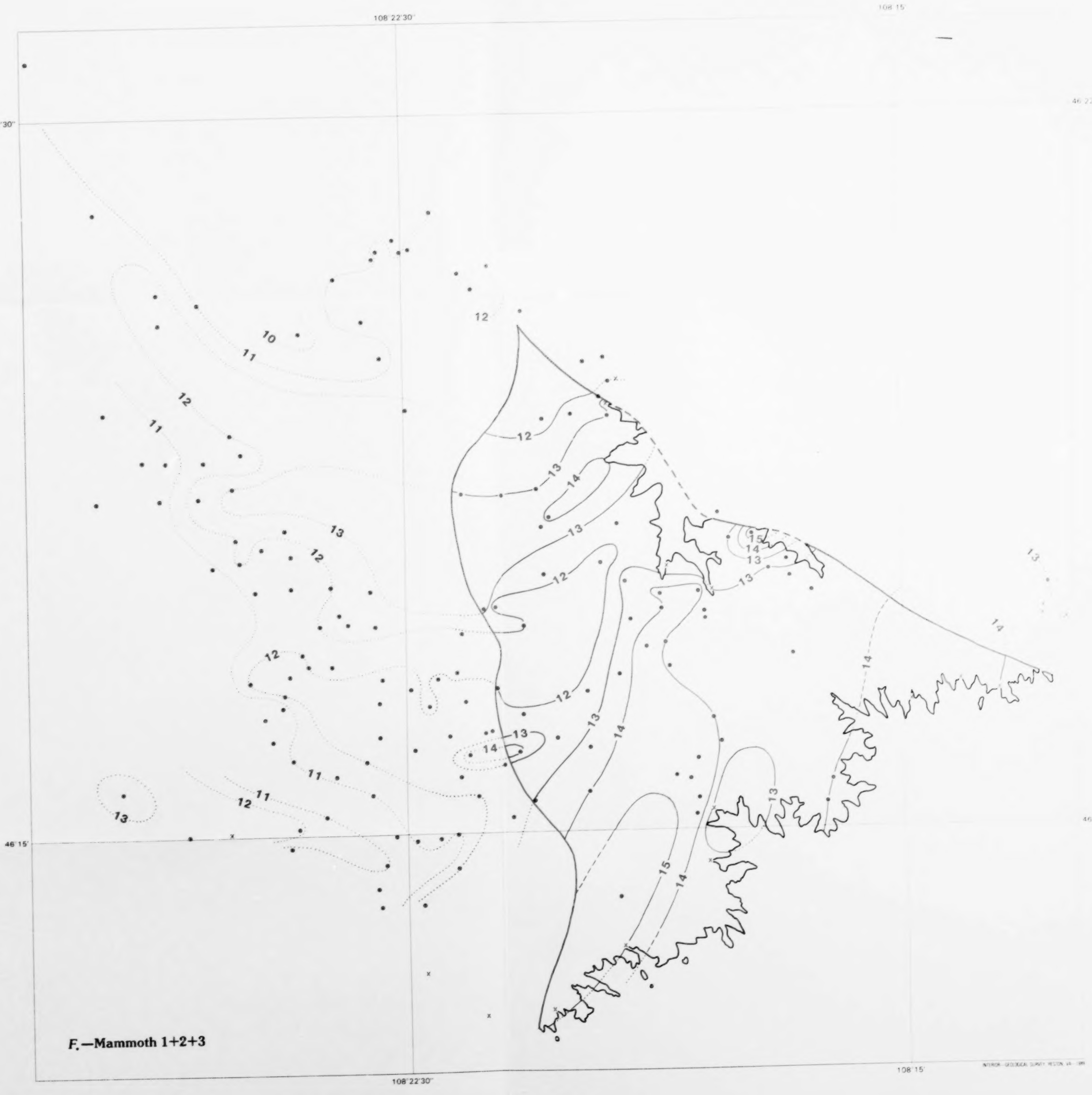
E.—Mammoth 2+3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F.—Mammoth 1+2+3

SCALE 1:50 000

1 ½ 0 1 2 3 MILES

Mammoth 1+2	Musselshell	6N. 27E	—	—	—	0	15.7	42.4	5.89	64.0	—	2.78	3.22	6.00	70.0	—	—	—	0	5.59
		7N. 26E	—	—	—	0	12.8	2.86	2.05	17.7	0.46	0.49	0.64	1.59	19.3	—	—	—	0	48.3
		7N. 27E	—	—	—	0	1.31	1.32	—	2.63	3.71	5.20	0.30	9.21	11.8	—	—	—	0	4.80
		8N. 26E	—	—	—	0	—	—	—	0	—	—	—	0	0	—	—	—	0	—
		Total	0	0	0	0	65.4	52.8	8.12	126	4.17	8.47	4.16	16.8	143	0	0	0	0	91.6
	Yellowstone	5N. 27E	—	—	—	0	0.29	—	—	0.29	1.31	—	—	1.31	1.60	—	—	—	0	—
		6N. 27E	—	—	—	0	3.79	0.91	0.45	5.15	0.13	—	0.15	0.28	5.43	—	—	—	0	4.97
		Total	0	0	0	0	4.08	0.91	0.45	5.44	1.44	0	0.15	1.59	7.03	0	0	0	0	4.97
		TOTAL	0	0	0	0	69.5	53.7	8.57	132	5.61	8.47	4.31	18.4	150	0	0	0	0	96.6
Mammoth 2+3	Musselshell	6N. 27E	—	—	—	0	0.47	—	—	0.47	—	—	—	0	0.47	—	—	—	0	0.77
		6N. 28E	—	—	—	0	4.06	—	—	4.06	—	—	—	0	4.06	—	—	—	0	17.6
		7N. 26E	0.18	—	—	0.18	—	—	—	0	—	—	—	0	0.18	0.05	—	—	0.05	—
		7N. 27E	—	—	—	0	5.26	0.25	—	5.51	—	—	—	0	5.51	0.22	—	—	0.22	7.11
		7N. 28E	—	—	—	0	3.47	—	—	3.47	—	—	—	0	3.47	—	—	—	0	12.7
		TOTAL	0.18	0	0	0.18	13.3	0.25	0	13.5	0	0	0	0	13.7	0.27	0	0	0.27	30.2
Mammoth 1+2+3	Musselshell	6N. 27E	—	—	—	0	—	—	—	0	37.4	28.5	16.6	82.5	82.5	—	—	—	0	—
		6N. 28E	—	—	—	0	—	—	—	0	10.2	1.79	—	12.0	12.0	—	—	—	0	—
		7N. 27E	—	—	—	0	—	—	—	0	9.92	6.70	0.08	16.7	16.7	—	—	—	0	—
		Total	0	0	0	0	0	0	0	0	57.5	37.0	18.7	111	111	0	0	0	0	0
	Yellowstone	5N. 27E	—	—	—	0	—	—	—	0	1.82	—	—	1.82	1.82	—	—	—	0	—
		6N. 27E	—	—	—	0	—	—	—	0	14.7	7.53	0.18	22.4	22.4	—	—	—	0	—

TOTAL	18.8	15.9	1.93	36.6	97.0	60.4	8.68	166	84.5	53.0	21.1	158	361	34.7	23.7	1.87	60.3	151	58.3	12.7	220	102	112	57.0	271	²551	31.2	12.7	0.77	44.7	80.3	21.8	2.88	105	3.67	16.1	13.4	33.1	183	1,100	1,120

[1] Overburden categories approximate. See text.

[2] Due to the vagaries of the rounding process, these column totals differ from the posted row totals in the last [illegible]

[3] Included but not posted are hypothetical resources—1.86 million short tons for thickness of >5–10 ft with overburden of 0–200 ft.

[4] Included but not posted are hypothetical resources—0.34 million short tons for thickness of >5–10 ft with overburden of 0–200 ft.

[5] These totals include the resources mentioned in footnotes 3 and 4.

[1] Includes resources for T. 8 N., R. 26 E.—0.21 million short tons for thickness of >5–10 ft.

Table 2.—*Proximate, ultimate, and associated analyses of 11 samples of Mammoth coal, compared with Powder River region coal samples*

[Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: 1, as received; 2, moisture free; 3, moisture and ash free. Samples D189148–D189151 analyzed by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa.; D221596–D221599 by U.S. Department of Energy; 5799, 6828, 6831 by U.S. Geological Survey. Values right of brace are weighted average, as-received basis, for upper and lower parts of a coal bed at a single locality. Kcal/kg=0.556 (Btu/lb); °C=(°F−32)÷1.8. Leaders (---), not applicable; ND, not determined]

Locality	Mammoth coal split	Sample No.	Sample type	Form of analyses	Air dry loss (percent)	Proximate analyses (percent): Moisture	Volatile matter	Fixed C	Ash	Ultimate analyses (percent): H	C	N	O	S	Forms of sulfur (percent): Sulfate	Pyritic	Organic	Fusibility of ash (°F)¹	Heat of combustion (Btu/lb)	Heat of combustion (Btu/lb), moist, mineral-matter free	Apparent rank²
84-C79	Mammoth 1+2 upper 5 ft	D189151		1	1.8	17.1	32.7	41.7	8.5	5.8	56.7	1.0	27.0	1.0	0.01	0.35	0.63	2,400	9,850		
				2	---	---	39.5	50.3	10.2	4.7	68.5	1.2	14.2	1.2	.01	.43	.76	2,490	11,890		
				3	---	---	44.0	56.0	---	5.3	76.3	1.3	15.8	1.3	.01	.48	.85	2,575	13,240		
	lower 5 ft	D189150	channel (Divide Mine)	1	2.9	17.6	31.8	44.8	5.8	6.0	59.0	1.0	27.4	.7	.01	.36	.37	2,255	10,290	10,950	hvCb or subA
				2	---	---	38.6	54.3	7.0	5.0	71.7	1.2	14.3	.9	.01	.44	.45	2,345	12,500		
				3	---	---	41.6	58.4	---	5.3	77.1	1.3	15.3	1.0	.01	.47	.48	2,425	13,440		
84-C78	Mammoth 1+2 upper 3.4 ft	D189149		1	2.4	18.3	32.4	42.8	6.5	5.7	58.0	0.9	28.0	0.9	0.01	0.46	0.42	2,195	10,040		
				2	---	---	39.7	51.2	10.1	4.7	69.3	1.1	13.8	1.1	.01	.55	.50	2,280	11,990		
				3	---	---	43.1	56.9	---	5.2	77.1	1.2	15.4	1.2	.01	.61	.56	2,360	13,340		
	lower 5 ft	D189148	channel (PM Mine)	1	2.6	10.8	32.0	44.8	5.6	6.0	58.9	1.0	26.4	1.2	.01	.76	.45	2,135	10,480	11,140	hvCb or subA
				2	---	---	39.4	53.9	6.7	4.9	72.0	1.2	13.8	1.5	.01	.91	.54	2,215	12,570		
				3	---	---	42.2	57.8	---	5.3	77.1	1.3	14.8	1.6	.01	.98	.58	2,305	13,470		
85-86C	Mammoth 1+2+3 upper 6.7 ft	D221596		1	ND	9.6	32.3	48.8	8.8	5.2	63.1	1.1	20.9	0.8	0.01	0.43	0.41	2,350	10,990		
				2	---	---	36.3	53.9	9.8	4.6	69.8	1.2	13.7	.9	.01	.48	.45	2,440	12,150		
				3	---	---	40.2	59.8	---	5.1	77.4	1.3	15.2	1.0	.01	.53	.50	2,530	13,470		
	lower 6.3 ft	D221597	core	1	ND	10.6	[illegible]	48.3	8.0	5.3	62.2	1.1	22.1	.6	.01	.25	.37	2,470	10,800	12,080	hvCb
				2	---	---	36.0	54.2	9.8	4.6	69.7	1.2	14.0	.7	.01	.28	.41	2,580	12,100		
				3	---	---	39.9	60.1	---	5.1	77.3	1.3	15.6	.8	.01	.31	.45	2,670	13,420		
85-79N	Mammoth 1+2+3 upper 7.9 ft	D221598		1	ND	11.3	31.0	49.4	8.3	5.3	62.7	1.0	21.7	0.9	0.01	0.55	0.37	2,180	10,780		
				2	---	---	34.9	55.7	9.4	4.6	70.7	1.1	13.1	1.0	.01	.62	.41	2,240	12,160		
				3	---	---	38.5	61.5	---	5.0	78.1	1.2	14.5	1.2	.01	.69	.46	2,330	13,420		
	lower 6.4 ft	D221599	core	1	ND	10.3	32.4	46.9	10.4	5.3	61.6	1.1	21.0	.7	.01	.35	.31	2,620	10,680	11,950	hvCb
				2	---	---	36.1	52.3	11.6	4.7	68.6	1.2	13.2	.7	.01	.39	.35	2,710	11,900		
				3	---	---	40.8	59.2	---	5.3	77.6	1.3	15.0	.8	.01	.44	.39	2,790	13,460		
C4-C16	Mammoth 1+2 lower 7 ft of 8.6 ft	⁴5799	channel	1	ND	17.4	31.2	45.1	6.3	5.4	59.0	0.9	27.8	0.5	ND	ND	ND	ND	10,120	10,880	hvCb or subA
85-87	Mammoth 2+3 lower 6 ft of upper 8.6 ft	⁴6831	channel	1	ND	17.4	31.2	48.1	3.3	ND	ND	ND	ND	0.4	ND	ND	ND	ND	10,280	10,580	hvCb or subA
	lower 5 ft	⁴6828	channel	1	ND	18.7	29.6	46.6	5.1	ND	ND	ND	ND	.8	ND	ND	ND	ND	9,890		
	Arithmetic mean, Mammoth coal samples⁵		---	1	ND	15.1	31.8	46.1	7.1	5.5	60.2	1.0	24.8	0.8	0.01	0.45	0.42	2,320 2,400 2,490	10,370	11,280	hvCb or subA
	Arithmetic mean, 13 Powder River region coal samples⁶		---	1	16.1	27.1	28.7	38.4	7.9	6.3	48.5	0.7	35.2	1.4	0.01	1.16	0.21	ND	8,370	9,180	subC

[1] The three numbers for each analysis are, in sequence, initial deformation of ash temperature, softening temperature, and fluid temperature.

[2] hvCb=high-volatile C bituminous; subA=subbituminous A; subC=subbituminous C. Computed according to standards of American Society for Testing and Materials (1973).

[3] These figures may not be accurate as the samples were not analyzed immediately and may have dried somewhat. These are splits of samples from a private company. Values reported here are about 10 percent higher than company values. The rank, however, remains the same.

[4] These analyses are reported in Woolsey and others (1917, p. 53).

[5] Calculated using weighted average for each locality.

[6] Derived from Swanson and others (1976, table 21B). "Powder River region" of Swanson and others is from Trumbull (1960), and is approximately equivalent to the Powder River basin.

Table 3.—*Major- and minor-oxide and trace-element compositions of the laboratory ash of eight coal samples from the Mammoth coal, compared with Powder River region coal samples*

[Coals were ashed at 525°C. L, less than value shown; N, not detected; leaders (---), not determined; -S, values listed were determined by semiquantitative spectrographic analysis. Spectrographic results for samples D189148–D189151 are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are reported arbitrarily as midpoints of those brackets, 1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. Precision of spectrographic data is approximately one bracket at 68-percent confidence, or two brackets at 95-percent confidence; confidence of values for samples D221596–D221599 ranges between plus 50 percent and minus 33 percent]

Locality	Mammoth coal split	Sample No.	Ash (percent)	SiO_2 (percent)	Al_2O_3 (percent)	CaO (percent)	MgO (percent)	Na_2O (percent)	K_2O (percent)	Fe_2O_3 (percent)	TiO_2 (percent)	SO_3 (percent)	Ag-S ppm	B-S ppm	Ba-S ppm	Be-S ppm	Cd ppm	Ce-S ppm	Cu ppm	Ga-S ppm	Ge-S ppm	La-S ppm	Li ppm	Mn ppm	Mo-S ppm	Nb-S ppm	Ni-S ppm	Pb ppm	Sc-S ppm	Sr-S ppm	V-S ppm	Y-S ppm	Yb-S ppm	Zn ppm	Zr-S ppm
84-C79	Mammoth 1+2 upper 5 ft	D189151	8.4	32	20	11	1.9	0.23	0.27	8.6	1.0	12	N	500	5,000	5	1.0	N	95	20	N	N	150	380	10	N	30	35	15	2,000	70	50	5	160	200
	lower 5 ft	D189150	7.1	34	22	7.7	2.7	.28	.35	11	.97	11	N	500	5,000	7	1.0L	N	93	30	N	N	130	510	10	N	15	50	10	1,500	70	50	5	75	150
84-C78	Mammoth 1+2 upper 3.4 ft	D189149	10.5	29	17	23	1.7	0.16	0.23	7.3	0.85	8.7	N	200	3,000	N	1.0L	N	92	20	N	N	87	620	10	N	15	45	10	1,500	70	50	5	76	150
	lower 5 ft	D189148	8.6	24	18	14	2.4	.18	.29	17	.83	12	N	500	7,000	10	1.0L	N	78	30	20	70	70	420	20	N	10	40	20	2,000	70	70	7	44	150
85-86C	Mammoth 1+2+3 upper 6.7 ft	D221596	8.9	41	25	8.0	1.2	2.6	0.37	7.3	0.94	---	0.92L	300	5,100	5.7	1.0L	170	96	42	7.4	67	130	370	12	62	27	42	16	2,700	120	62	5.2	120	1,100
	lower 6.3 ft	D221597	9.8	45	28	4.9	1.0	2.4	.42	4.6	.90	---	.92L	340	3,200	8.9	1.0L	180	95	43	12	85	100	330	7.6	62	31	51	21	2,400	160	90	6.1	81	890
85-79N	Mammoth 1+2+3 upper 7.9 ft	D221598	9.2	41	21	5.5	1.5	2.6	0.78	9.0	1.2	---	0.97	350	2,600	6.9	2.0	160	77	36	6.7	64	110	370	16	43	27	25L	15	2,600	150	55	4.9	59	720
	lower 6.4 ft	D221599	12.1	45	28	4.1	.83	1.9	.41	4.9	.92	---	.92L	340	5,700	8.2	1.0L	180	88	57	11	69	130	240	9.1	57	26	48	19	2,100	170	67	5.5	92	750
	Arithmetic mean, Mammoth coal samples¹		8.9	36	22	9.5	1.7	1.3	0.40	9.0	0.98	11.4	0.93L	390	4,800	7.7L	1.0L	170L	88	34	13L	71L	120	400	12	56L	22	41L	18	2,200	110	62	5.4	85	520
	Arithmetic mean, 410 Powder River region coal samples²		9.9	30	14	18	4.0	1.8	0.50	7.3	0.88	17	---	---	---	---	0.8	---	123	---	---	---	58	---	---	---	---	88	---	---	---	---	---	200	---

[1] Calculated using weighted average for each locality.

[2] From Hatch and Swanson (1977, table 6A). "Powder River region" of Hatch and Swanson is from Trumbull (1960), and is approximately equivalent to the Powder River basin.

Table 4.—*Content of 40 elements in eight coal samples from the Mammoth coal, reported on whole-coal basis, compared with Powder River region coal samples*

[As, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) coal; remaining analyses calculated from determinations on ash. -S, content determined by semiquantitative spectrographic analysis (see table 3). L, less than value shown; N, not detected; leaders (---), not determined]

Locality	Mammoth coal split	Sample No.	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	Ag-S ppm	As ppm	B-S ppm	Ba-S ppm	Be-S ppm	Cd ppm	Ce-S ppm	Co ppm	Cr ppm	Cu ppm	F ppm	Ga-S ppm	Ge-S ppm	Hg ppm	La-S ppm	Li ppm	Mn ppm	Mo-S ppm	Nb-S ppm	Ni-S ppm	Pb ppm	Sb ppm	Sc-S ppm	Se ppm	Sr-S ppm	Th ppm	U ppm	V-S ppm	Y-S ppm	Yb-S ppm	Zn ppm	Zr-S ppm
84-C79	Mammoth 1+2 upper 5 ft	D189151	1.3	0.89	0.66	0.094	0.014	0.019	0.50	0.050	N	2.2	50	500	0.5	0.084	N	1.8	2.9	8.0	35	1.5	N	0.11	N	13	32	1	N	2	2.9	0.40	1.5	0.10L	150	1.5	1.2	7	5	0.5	13	15
	lower 5 ft	D189150	1.1	.83	.39	.11	.015	.021	.55	.041	N	1.3	30	300	.5	.071L	N	1.3	2.5	6.6	20L	2	N	.04	N	9.4	36	.7	N	1	3.8	.43	.7	.40	100	1.5	1.1	5	3	.3	5.3	10
84-C78	Mammoth 1+2 upper 3.4 ft	D189149	1.4	0.94	1.7	0.10	0.012	0.020	0.54	0.053	N	3.8	20	300	N	0.11L	N	1.1	3.3	9.7	20	2	N	0.11	N	9.1	65	1	N	1.5	4	0.40	1	0.52	150	1.5	1.7	7	5	0.5	8.0	15
	lower 5 ft	D189148	.74	.58	.66	.080	.009	.016	.78	.033	N	3.1	30	500	.7	.060L	N	1.2	2.5	5.1	20L	2	1.5	.07	5	4.6	28	1.5	N	.7	2.6	1.3	1.5	.25	150	1.2	1.4	5	5	.5	2.9	10
85-86C	Mammoth 1+2+3 upper 6.7 ft	D221596	1.7	1.2	0.38	0.084	0.17	0.027	0.45	0.050	0.082L	1.6	27	450	0.51	0.089L	15	0.78	2.9	7.7	20	3.7	0.66	0.12	6.0	12	33	1.1	5.5	2.4	3.7	0.67	1.4	0.98	240	1.9	1.4	11	5.5	0.46	10	98
	lower 6.3 ft	D221597	2.0	1.4	.34	.056	.17	.034	.31	.062	.088L	2.0	33	310	.86	.090L	18	1.1	3.6	8.1	20	4.1	1.2	.07	8.2	15	31	.73	6.0	3.0	4.9	.94	2.0	.74	230	2.2	1.4	15	8.6	.59	5.9	95
85-79N	Mammoth 1+2+3 upper 7.9 ft	D221598	1.7	1.0	0.36	0.081	0.18	0.061	0.58	0.084	0.089	2.1	32	240	0.63	0.18	15	0.75	2.8	7.1	25	3.3	0.62	0.07	5.9	10	34	1.5	4.0	2.5	2.3L	0.46	1.4	0.54	240	1.1	1.2	14	5.1	0.45	5.4	66
	lower 6.4 ft	D221599	2.5	1.6	.35	.060	.17	.041	.41	.087	.11L	1.0	41	680	.99	.12L	22	.87	3.7	11	25	6.9	1.3	.06	8.3	16	29	1.1	6.9	3.1	5.8	1.2	2.3	---	250	2.5	1.4	21	8.1	.67	11	91
	Arithmetic mean, Mammoth coal samples¹		1.5	1.1	0.68	0.083	0.094	0.030	0.52	0.051	0.098L	2.2	33	410	0.67L	0.10L	17L	1.1	3.0	7.9	23L	3.2	1.1L	0.08	6.4L	11	35	1.1	5.5L	2.1	3.7L	0.74	1.5	0.56L	190	1.6	1.3	10	5.8	0.49	7.5	50
	Arithmetic mean, 410 Powder River region coal samples²		1.5	0.78	1.1	0.21	0.11	0.048	0.54	0.041	---	3	70	300	0.7	0.09	---	2	7	11.2	49	3	---	0.11	---	5.8	51	2	1.5	5	6.4	0.6	2	1.0	200	4.3	0.9	15	5	0.5	20	15

[1] Calculated using weighted average for each locality.

[2] From Hatch and Swanson (1977, table 6B). "Powder River region" of Hatch and Swanson is from Trumbull (1960), and is approximately equivalent to the Powder River basin.

INTRODUCTION

The Mammoth coal bed is of subbituminous A to high-volatile C bituminous apparent rank, averaging 12.5 ft thick and underlying an area of 85 mi². It lies about 1,000 ft above the base of the Tongue River Member of the Paleocene Fort Union Formation, as defined by Woolsey and others (1917), in south-central Montana's Bull Mountain basin (figs. 1 and 2). Part A of this Coal Investigations series includes maps showing the outcrop, structure, cross sections, and isopachs of partings of the Mammoth coal bed (Connor, 1988). This part, part B, contains maps showing the geographic location of the boundaries between Mammoth coal splits, isopachs of the splits, and the overburden thickness, and tables showing coal resources and coal quality. The outcrop and locality map of part A is also included here. Available data for all drill holes and most surface localities have been entered in the NCRDS (National Coal Resources Data System) of the U.S. Geological Survey, Reston, VA 22092, and have been published by C. W. Connor and L. R. H. Biewick (USGS Open-File Report 89–6).

SPLITS OF MAMMOTH COAL BED

The Mammoth coal bed is made up of three splits, separated by two partings of fluvial origin that range from less than an inch to more than 50 ft thick. The three splits were designated in part A of this series as, from base to top, Mammoth 1, Mammoth 2, and Mammoth 3. Mammoth 3 is equivalent to the Rehder split of earlier authors (Woolsey and others, 1917). Where these splits join they are designated Mammoth 1+2, Mammoth 2+3, and Mammoth 1+2+3. This is diagrammed in figure 3. Note that geographic boundaries between the various combinations of splits are not drawn where the splits diverge, but (for resource calculation purposes) are drawn where the thickness of a parting exceeds the thickness of either the overlying or underlying coal split. Data points used in determining these boundaries, the outcrop line, and the isopachs are shown in figure 4, and the map locations of the boundary lines and the 200- and 500-ft overburden lines are shown in figure 5.

ISOPACHS OF SPLITS

The splits of the Mammoth coal bed are isopached in figures 6*A–F*. Because the splits can be identified beyond the arbitrary boundaries described above, they are isopached as far beyond those boundaries as they can be recognized (dotted lines). Each of these maps displays all the data points used in constructing that particular map.

The average thicknesses of the Mammoth coal splits, to the nearest half foot, are as follows: Mammoth 1, 5.5 ft; Mammoth 2, 3 ft; Mammoth 3, 2.5 ft; Mammoth 1+2, 9 ft; Mammoth 2+3, 7.5 ft; Mammoth 1+2+3, 13.5 ft.

Two interesting features that suggest the controls on the thicknesses might be pointed out. The uppermost split, Mammoth 3 (fig. 6*C*), overlies a thick parting that has been identified as channel and overbank splay deposits (Connor, 1988). As Mammoth 3 is thickest on the flanks of this deposit (the two long northwest-trending areas more than 2.5 ft thick) and thins over the top of the channel (the linear less than 2-ft-thick area between the thicker areas), and as the configuration and position of the thinner area closely coincides with the thickest (center) part of the underlying channel deposit, environmental control is strongly suggested.

Structural control is suggested in two other isopach maps. Mammoth isopachs generally trend northwest, but in the south-central part of the region, in the southeast corner of the area of Mammoth 1+2 (fig. 6*D*) and in the southern two-thirds of Mammoth 1+2+3 (fig. 6*F*), the trend is northeast. This is the area that contains the thickest coal. The existence of a growth fault is suggested, but it is equally possible that the trend change is an artifact of data distribution.

COAL RESOURCES

The Mammoth coal is commonly oxidized on outcrop, but roadcut exposures of this and other coals in the Bull Mountains give evidence that oxidation has generally progressed only a few tens of feet to a hundred feet or so from the surface. Because coal loss due to oxidation is probably minor, it is not taken into consideration in resource estimates.

Resources reported in table 1*A* were calculated according to guidelines in U.S. Geological Survey Circular 891, "Coal resource classification system of the U.S. Geological Survey" (Wood and others, 1983). According to that currently standard USGS method, "measured" resources lie within a radius of 1/4 mi from a data point, "indicated" resources lie between 1/4 and 3/4 mi from a data point, "inferred" resources lie between 3/4 and 3 mi from a data point, and "hypothetical" resources lie beyond 3 mi from a data point. Although these categories suggest different degrees of certainty in reported values, that certainty cannot be quantified.

By way of contrast, in the kriging method of resource analysis (well described in Mousset-Jones, 1980), tonnage estimates can have confidence limits attached at any desired confidence level—a very desirable attribute. Resources for the Mammoth coal bed have already been reported using that statistical method (Pierce and others, 1983). The estimates according to the kriging method are included here (table 1*B*) but in a different format than in the original publication, for convenience in comparison with the standard USGS results.

Tonnages based on the two resource estimation methods are for the most part similar (last column, tables 1*A* and 1*B*). The totals for Mammoth 1, Mammoth 2, Mammoth 1+2, and Mammoth 1+2+3, as well as the grand total for the Mammoth, are within 2–5 percent of each other. The Mammoth 2+3 totals are within 11 percent. The Mammoth 3 totals differ by 32 percent, for some unknown reason. Comments in the rest of this section refer only to the standard USGS estimates in table 1*A*.

Coal tonnages are reported by split and location in categories according to qualitative degree of certainty, thickness, and overburden. Thickness categories (net coal, partings excluded) are 2.5–5 ft, >5–10 ft, and >10–20 ft. Coal less than 2.5 ft thick is excluded. Overburden categories are 0–200 ft, >200–500 ft, and >500 ft. The coal weight used in the calculations was 1,770 short tons per acre-foot.

Total tonnage for the Mammoth coal bed is estimated at 1.1 billion short tons. Total "measured" resources are 361 million short tons, "indicated" resources are 551 million short tons, and "inferred" resources are 183 million short tons. Tonnages by split and split combinations are, in millions of short tons: Mammoth 1, 121; Mammoth 2, 30.8; Mammoth 3, 46.2; Mammoth 1+2, 434; Mammoth 2+3, 108; and Mammoth 1+2+3, 357. Tonnages by thickness categories are: 2.5–5 ft, 142 million short tons; >5–10 ft, 491 million short tons; and >10–20 ft, 462 million short tons.

Tonnages by overburden category require some explanation. The overburden lines (fig. 5) were drawn relative to the top of the whole Mammoth package (that is, from the top of Mammoth 3, Mammoth 2+3, and Mammoth 1+2+3; see diagram, fig. 3), so resource estimates tabulated by overburden category are best for those splits. There is somewhat more overburden above the other three splits, but this can be ignored for Mammoth 1 and Mammoth 2 because the extra overburden amounts to less than 20 ft over most of their areas. Mammoth 1+2, however, has an extra 30–50 ft of overburden over much of its area (the channel sandstone discussed and isopached in part A), so some of its tabulated resources actually belong in the next thicker overburden category. Total Mammoth resources as reported by overburden category are: 603 million short tons under 0–200 ft of overburden, 372 million short tons under >200–500 ft of overburden, and 120 million short tons under >500 ft of overburden. Maximum overburden is about 800 ft, in the central parts of the two largest 500-ft overburden closures.

The township with the greatest resources is T. 6 N., R. 27 E., with 435 million short tons. Other townships with large resources, 140–180 million short tons, are T. 6 N., R. 28 E., T. 7 N., R. 26 E., and T. 7 N., R. 27 E. The other four townships underlain by the Mammoth coal bed each have less than 100 million short tons.

The possibility of roof problems in mining should be considered particularly for Mammoth 1+2, which is overlain by channel and splay deposits that are in turn overlain by Mammoth 3. Horne and others (1977, p. 89, 96–99) have demonstrated that "where splay deposits occur directly over a minable coal, are less than 20 ft (6 m) thick, and have a rider coal or extensively rooted zone over the top of the splay, severe roof problems may be encountered during mining." About half of Mammoth 1+2 meets these criteria, and that area may be delineated by overlaying the Mammoth 1+2 map (fig. 6*D*) with the isopach of the channel and splay deposits ("upper parting") in part A of this series.

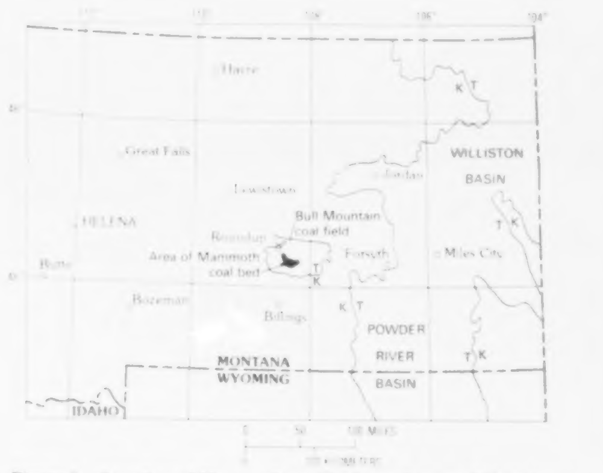

Figure 1.—Location of Mammoth coal bed, south-central Montana. Bull Mountain coal field and Powder River basin and Williston basin boundaries drawn at K-T (Cretaceous-Tertiary) boundary. Modified from American Association of Petroleum Geologists (1972).

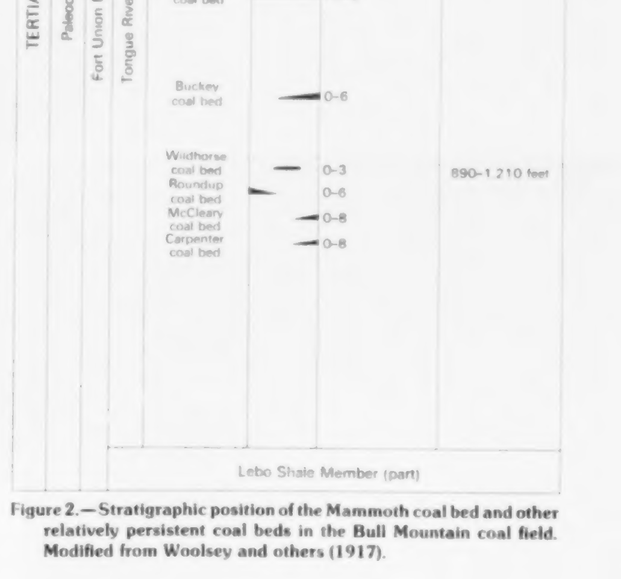

Figure 2.—Stratigraphic position of the Mammoth coal bed and other relatively persistent coal beds in the Bull Mountain coal field. Modified from Woolsey and others (1917).

COAL QUALITY

Based on analyses of 11 samples at six localities (table 2), the Mammoth coal contains an average (arithmetic mean) of 31.8 percent volatile matter, 7.1 percent ash, and 0.8 percent sulfur, about half of which is pyritic and half organic. Its apparent rank is subbituminous A to high-volatile C bituminous, as the heat of combustion on an as-received, moist, mineral-matter-free basis ranges from 10,580 to 12,080 Btu/lb and averages 11,260 Btu/lb. Vitrinite reflectance values of 0.4–0.5 percent (Daniel, 1982) on coal samples from the same localities as the first four localities listed on table 2 indicate the same range in apparent rank reported here. The relationship of vitrinite reflectance to coalification stages is discussed in Davis (1978) and summarized on table 4 of that publication.

The Mammoth coal of the Bull Mountain basin is of higher quality than Powder River basin coals deposited at about the same time, before the individual basins formed. Mammoth coal is of higher apparent rank (Powder River region coals are, on the average, subbituminous C), and the sulfur content is about half that of the Powder River region coal (table 2, last row). Furthermore, trace-element analyses of eight Mammoth coal samples from four localities (tables 3 and 4), when compared with Powder River region coal samples (last row, both tables), show that the Mammoth samples have about half as much of the commonly considered potentially toxic B, F, Mo, Pb, and Se. Toxicity hazards from environmental concentrations of these elements are discussed in Gough and others (1979). There may be fewer such hazards with the Mammoth coal than with the Powder River region coals. Only two elements occur in the Mammoth samples in considerably greater concentration than in the Powder River region (in fact, they are three to four times more abundant): Nb and Zr. The larger amounts of these elements, probably held in the heavy minerals, may be due to the Mammoth coal bed area having been closer to early Tertiary sources of volcanic ash than the Powder River area. Nb and Zr are unlikely environmental hazards.

ACKNOWLEDGMENTS

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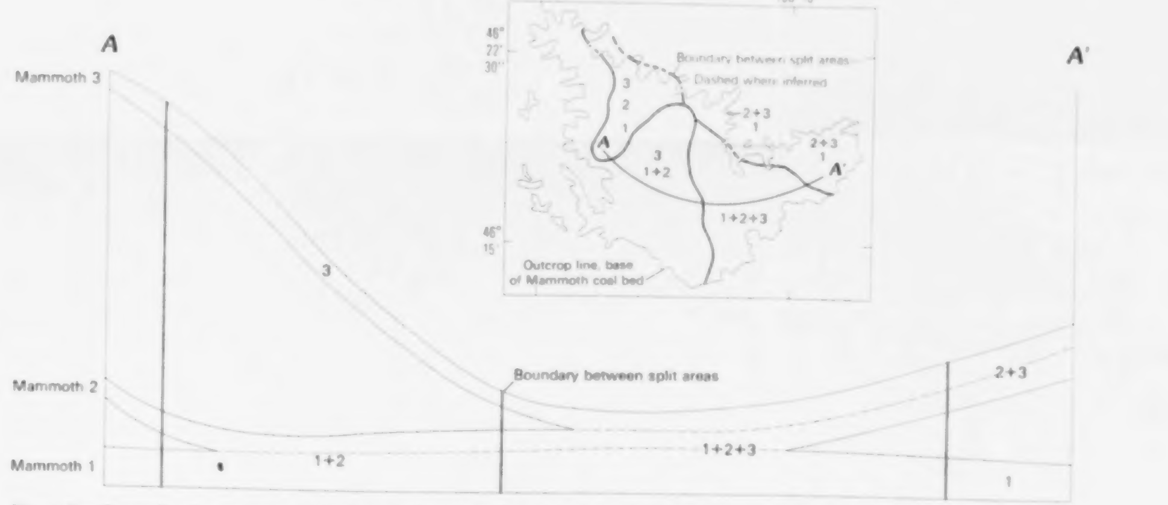

Figure 3.—Generalized cross section (see inset for location) showing designations of Mammoth coal splits. Note that the boundaries between split areas are drawn where a parting exceeds the thickness of the split either above or below.

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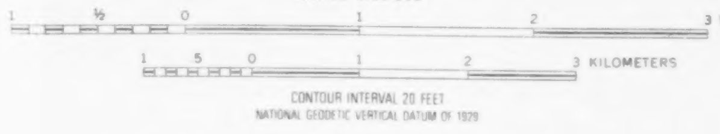


MAPS SHOWING COAL-SPLIT BOUNDARIES, ISOPACHS OF COAL SPLITS, COAL RESOURCES, AND COAL QUALITY—MAMMOTH COAL BED, PALEOCENE TONGUE RIVER MEMBER OF THE FORT UNION FORMATION, BULL MOUNTAIN COAL FIELD, SOUTH-CENTRAL MONTANA

By

Carol Waite Connor

1989

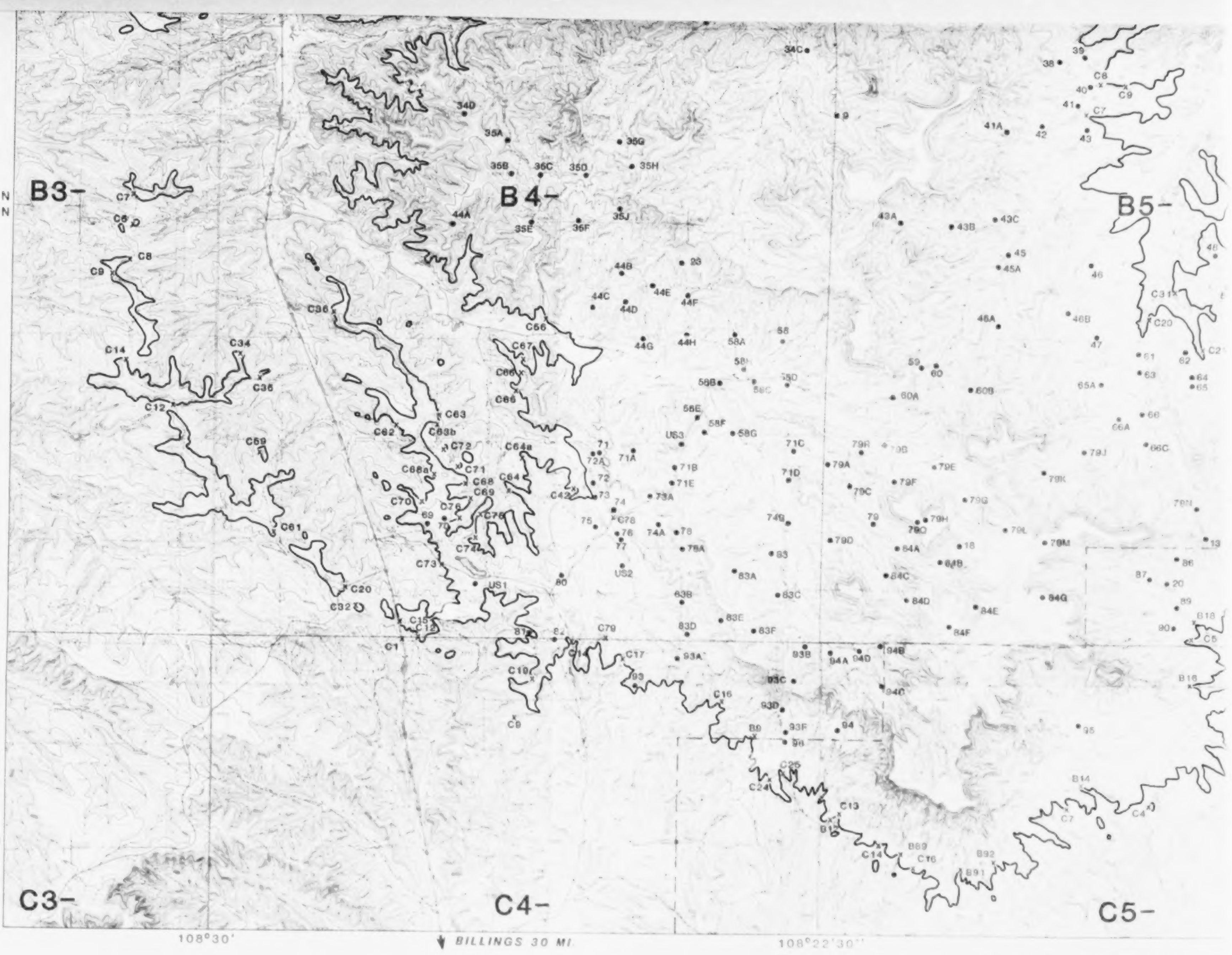
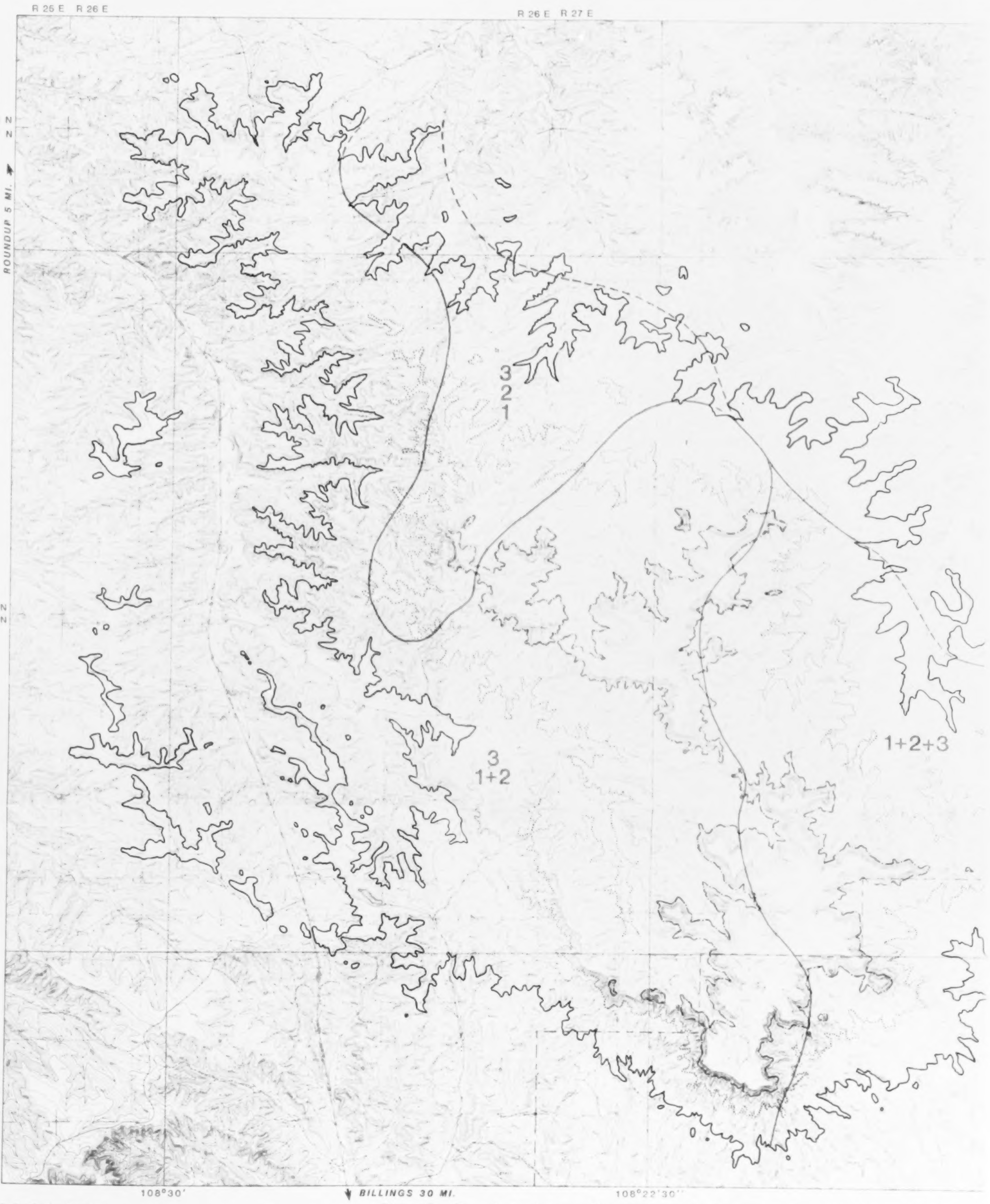


Figure 4.—Outcrop and locality map, Mammoth coa



Base from U.S. Geological Survey, 1:24,000, Cherry Spring, Chimney Butte, Dunn Mountain North, Dunn Mountain South, Gage, Gage NE, Hanger Coulee, Hay Basin NE, PK Ranch, Pole Coulee, Roundup and Signal Mountain, unedited advanced prints

Figure 5.—Boundaries between Mammoth coal-split areas, and overburden lines measured

best copy available

48.4	—	—	—	0	—	0.03	0.04	0.07	—	0.03	3.36	3.39	4.39	171
56.3	—	—	—	0	29.1	0.05	0.08	29.2	—	—	—	0	29.2	⁶105
45.6	—	—	—	0	—	2.50	1.14	3.94	0.31	6.69	3.53	10.6	14.1	71.3
0	—	—	—	0	5.23	—	—	5.23	—	—	—	0	5.23	5.23
184	0	0	0	0	43.4	2.58	2.04	48.0	0.31	6.72	6.69	13.8	61.9	⁵392
2.16	—	—	—	0	—	—	—	0	—	—	—	0	0	3.76
22.8	—	—	—	0	—	—	0.50	0.50	0.14	3.57	6.48	10.2	10.7	38.9
25.0	0	0	0	0	0	0	0.50	0.50	0.14	3.57	6.48	10.2	10.7	42.7
208	0	0	0	0	43.4	2.58	2.54	48.5	0.45	10.3	13.4	24.1	72.6	⁵434
0.77	—	—	—	0	—	—	—	0	—	—	—	0	0	1.24
23.9	—	—	—	0	11.5	13.4	0.31	25.2	—	—	—	0	25.2	53.2
0.05	0.02	—	—	0.02	—	—	—	0	—	—	—	0	0.02	0.25
7.47	0.12	—	—	0.12	2.57	—	—	2.57	—	—	—	0	2.69	15.7
14.9	—	—	—	0	14.8	5.08	0.03	19.7	—	—	—	0	19.7	38.1
47.1	0.14	0	0	0.14	28.7	18.5	0.34	47.5	0	0	0	0	47.6	108
67.9	—	—	—	0	—	—	—	0	—	0.46	—	0.46	0.46	171
14.0	—	—	—	0	—	—	—	0	1.45	5.30	—	6.75	6.75	52.8
23.4	—	—	—	0	—	—	—	0	—	—	—	0	0	40.1
105	0	0	0	0	0	0	0	0	1.45	5.76	0	7.21	7.21	263
0	—	—	—	0	—	—	—	0	—	—	—	0	0	1.82
56.6	—	—	—	0	—	—	—	0	1.77	0.05	—	1.82	1.82	80.6
5.87	—	—	—	0	—	—	—	0	—	—	—	0	0	10.7
62.3	0	0	0	0	0	0	0	0	1.77	0.05	0	1.82	1.82	93.2
208	0	0	0	0	0	0	0	0	3.22	5.81	0	9.03	9.03	367
¹551	31.2	12.7	0.77	44.7	80.3	21.8	2.88	105	3.67	16.1	13.4	33.1	183	1,100

—	105 (±1.06)	17.0 (±0.17)	122
4.23 (±0.08)	87.5 (±1.75)	—	91.7
—	48.2 (±0.96)	17.6 (±0.35)	65.8
1.39 (±0.46)	0.44 (±0.14)	—	1.83
5.62	332	34.6	372
—	3.14 (>±2.82)	—	3.14
—	15.3 (±0.61)	22.6 (±0.90)	37.9
0	18.4	22.6	41.0
5.62	350	57.2	413
—	1.41 (>±1.27)	—	1.41
—	54.0 (±4.32)	—	54.0
0.38 (>±0.32)	—	—	0.38
0.58 (±0.07)	16.4 (±1.97)	—	17.0
—	31.3 (±4.07)	16.6 (±2.16)	47.9
0.92	103	16.6	121
—	—	173 (±0.86)	173
—	—	52.5 (±0.52)	52.5
—	—	41.0 (±0.41)	41.0
0	0	267	267
—	—	2.74 (±0.66)	2.74
—	—	84.4 (±0.84)	84.4
—	—	11.2 (±0.34)	11.2
0	0	98.3	98.3
0	0	385	385
138	548	439	1,120

¹Includes resources for T. 8 N., R. 26 E.—0.21 million short tons for thickness of >5–10 ft.

Table 3.—Major- and minor-oxide and trace-element compositions of the laboratory ash of eight coal samples from the Mammoth coal, compared with Powder River region coal samples

[Coals were ashed at 525 °C. L, less than value shown; N, not detected; leaders (---), not determined. -S, values listed were determined by semiquantitative spectrographic analysis. Spectrographic results for samples D189148–D189151 are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are reported arbitrarily as midpoints of those brackets, 1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. Precision of spectrographic data is approximately one bracket at 68-percent confidence, or two brackets at 95-percent confidence; confidence of values for samples D221596–D221599 ranges between plus 50 percent and minus 33 percent]

	Sample No.	Ash (percent)	SiO₂ (percent)	Al₂O₃ (percent)	CaO (percent)	MgO (percent)	Na₂O (percent)	K₂O (percent)	Fe₂O₃ (percent)	TiO₂ (percent)	SO₃ (percent)	Ag-S ppm	B-S ppm	Ba-S ppm	Be-S ppm	Cd ppm	Ce-S ppm	Cu ppm	Ga-S ppm	Ge-S ppm	La-S ppm	Li ppm	Mn ppm	Mo-S ppm	Nb-S ppm	Ni-S ppm	Pb ppm	Sc-S ppm	Sr-S ppm	V-S ppm	Y-S ppm	Yb-S ppm	Zn ppm	Zr-S ppm
+2 5 ft	D189151	8.4	32	20	11	1.9	0.23	0.27	8.6	1.0	12	N	500	5,000	5	1.0	N	95	20	N	N	150	380	10	N	30	35	15	2,000	70	50	5	100	200
5 ft	D189150	7.1	34	22	7.7	2.7	.28	.35	11	.97	11	N	500	5,000	7	1.0L	N	93	30	N	N	130	510	10	N	15	50	10	1,500	70	50	5	75	150
1+2 3.4 ft	D189149	10.5	29	17	23	1.7	0.16	0.23	7.3	0.85	8.7	N	200	3,000	N	1.0L	N	92	20	N	N	87	620	10	N	15	45	10	1,500	70	50	5	78	150
5 ft	D189148	6.6	24	16	14	2.4	.16	.29	17	.83	12	N	500	7,000	10	1.0L	N	78	30	20	70	70	420	20	N	10	40	20	2,000	70	70	7	44	150
1+2+3 6.7 ft	D221596	8.9	41	25	6.0	1.2	2.6	0.37	7.3	0.94	---	0.92L	300	5,100	5.7	1.0L	170	86	42	7.4	87	130	370	12	82	27	42	16	2,700	120	82	5.2	120	1,100
6.3 ft	D221597	9.6	45	28	4.9	1.0	2.4	.42	4.6	.90	---	.92L	340	3,200	8.9	1.0L	190	95	43	12	86	160	330	7.8	82	31	51	21	2,400	160	90	6.1	81	990
1+2+3 7.9 ft	D221598	9.2	41	21	5.5	1.5	2.6	0.79	9.0	1.2	---	0.97	350	2,600	6.9	2.0	100	77	36	6.7	64	110	370	16	43	27	25L	15	2,800	150	56	4.9	58	720
6.4 ft	D221599	12.1	45	28	4.1	.83	1.9	.41	4.9	.92	---	.92L	340	5,700	8.2	1.0L	100	88	57	11	60	130	240	9.1	57	28	48	19	2,100	170	87	5.5	92	750
mean, Mammoth es¹		8.9	36	22	9.5	1.7	1.3	0.40	9.0	0.96	11.4	0.93L	380	4,600	7.7L	1.0L	170L	88	34	13L	71L	120	400	12	58L	22	41L	16	2,200	110	62	5.4	86	520
mean, 410 Powder coal samples²		9.9	30	14	18	4.0	1.8	0.50	7.3	0.68	17	---	---	---	---	0.8	---	123	---	---	---	58	---	---	---	---	98	---	---	---	---	---	208	---

...ono weighted average for each locality.

...and Swanson (1977, table 6A). "Powder River region" of Hatch and Swanson is from Trumbull (1960), and is approximately equivalent to the Powder River basin.

...able 4.—Content of 40 elements in eight coal samples from the Mammoth coal, reported on whole-coal basis, compared with Powder River region coal samples

[As, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32 °C) coal; remaining analyses calculated from determinations on ash. -S, content determined by semiquantitative spectrographic analysis (see table 3). L, less than value shown; N, not detected; leaders (---), not determined]

Sample No.	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	Ag-S ppm	As ppm	B-S ppm	Ba-S ppm	Be-S ppm	Cd ppm	Ce-S ppm	Co ppm	Cr ppm	Cu ppm	F ppm	Ga-S ppm	Ge-S ppm	Hg ppm	La-S ppm	Li ppm	Mn ppm	Mo-S ppm	Nb-S ppm	Ni-S ppm	Pb ppm	Sb ppm	Sc-S ppm	Se ppm	Sr-S ppm	Th ppm	U ppm	V-S ppm	Y-S ppm	Yb-S ppm	Zn ppm	Zr-S ppm
D189151	1.3	0.89	0.06	0.094	0.014	0.019	0.50	0.050	N	2.2	50	500	0.5	0.084	N	1.8	2.9	8.0	35	1.5	N	0.11	N	13	32	1	N	2	2.9	0.40	1.5	0.10L	150	1.5	1.2	7	5	0.5	13	15
D189150	1.1	.83	.39	.11	.015	.021	.55	.041	N	1.3	30	300	.5	.071L	N	1.3	2.5	6.8	20L	2	N	.04	N	9.4	38	.7	N	1	3.6	.43	.7	.40	100	1.5	1.1	5	3	.3	5.3	10
D189149	1.4	0.94	1.7	0.10	0.012	0.020	0.54	0.053	N	3.8	20	300	N	0.11L	N	1.1	3.3	9.7	20	2	N	0.11	N	9.1	65	1	N	1.5	4.7	0.40	1	0.52	150	1.5	1.7	7	5	0.5	8.0	15
D189148	.74	.56	.66	.096	.009	.016	.78	.033	N	3.1	30	500	.7	.086L	N	1.2	2.5	5.1	20L	2	1.5	.07	.5	4.6	28	1.5	N	.7	2.8	1.3	1.5	.25	150	1.2	1.4	5	5	.5	2.9	10
D221596	1.7	1.2	0.38	0.064	0.17	0.027	0.45	0.050	0.082L	1.6	27	450	0.51	0.089L	15	0.76	2.9	7.7	20	3.7	0.66	0.12	8.0	12	33	1.1	5.5	2.4	3.7	0.87	1.4	0.98	240	1.9	1.4	11	5.5	0.46	10	98
D221597	2.0	1.4	.34	.058	.17	.034	.31	.052	.088L	2.0	33	310	.65	.098L	18	1.1	3.6	9.1	20	4.1	1.2	.07	8.2	15	31	.73	6.0	3.0	4.5	.94	2.0	.74	230	2.2	1.4	15	8.8	.58	5.9	95
D221598	1.7	1.0	0.36	0.081	0.18	0.061	0.58	0.064	0.089	2.1	32	240	0.63	0.18	15	0.75	2.6	7.1	25	3.3	0.82	0.07	5.9	10	34	1.5	4.0	2.5	2.3L	0.48	1.4	0.54	240	1.1	1.2	14	5.1	0.45	5.4	66
D221599	2.5	1.8	.35	.060	.17	.041	.41	.067	.11L	1.0	41	690	.99	.12L	22	.97	3.7	11	25	6.9	1.3	.06	8.3	16	29	1.1	6.9	3.1	5.8	1.2	2.3	---	250	2.5	1.4	21	8.1	.67	11	91
...mmoth	1.6	1.1	0.66	0.083	0.094	0.030	0.52	0.051	0.098L	2.2	33	410	0.67L	0.10L	17L	1.1	3.0	7.9	23L	3.2	1.1L	0.08	6.4L	11	35	1.1	5.5L	2.1	3.7L	0.74	1.5	0.50L	190	1.8	1.3	10	5.8	0.49	7.5	50
...Powder ...mples²	1.5	0.78	1.1	0.21	0.11	0.048	0.54	0.041		3	70	300	0.7	0.09	---	2	7	11.2	49	3	---	0.11	---	5.9	51	2	1.5	5	6.4	0.6	2	1.0	200	4.3	0.9	15	5	0.5	20	15

...ighted average for each locality.

...anson (1977, table 6B). "Powder River region" of Hatch and Swanson is from Trumbull (1960), and is approximately equivalent to the Powder River basin.

...–200 ft of overburden, 372 million ...erburden, and 120 million short tons ...num overburden is about 800 ft, in the ... ft overburden closures.

...resources is T. 6 N., R. 27 E., with 435 ...with large resources, 140–180 million ...N., R. 26 E., and T. 7 N., R. 27 E. The ...he Mammoth coal bed each have less

...ms in mining should be considered ...ich is overlain by channel and splay ...Mammoth 3. Horne and others (1977, ...) that "where splay deposits occur ...than 20 ft (6 m) thick, and have a rider ...ver the top of the splay, severe roof ...ng mining." About half of Mammoth ...area may be delineated by overlaying ...th the isopach of the channel and splay ...A of this series.

COAL QUALITY

Based on analyses of 11 samples at six localities (table 2), the Mammoth coal contains an average (arithmetic mean) of 31.8 percent volatile matter, 7.1 percent ash, and 0.8 percent sulfur, about half of which is pyritic and half organic. Its apparent rank is subbituminous A to high-volatile C bituminous, as the heat of combustion on an as-received, moist, mineral-matter-free basis ranges from 10,580 to 12,080 Btu/lb and averages 11,260 Btu/lb. Vitrinite reflectance values of 0.4–0.5 percent (Daniel, 1982) on coal samples from the same localities as the first four localities listed on table 2 indicate the same range in apparent rank reported here. The relationship of vitrinite reflectance to coalification stages is discussed in Davis (1978) and summarized on table 4 of that publication.

The Mammoth coal of the Bull Mountain basin is of higher quality than Powder River basin coals deposited at about the same time, before the individual basins formed. Mammoth coal is of higher apparent rank (Powder River region coals are, on the average, subbituminous C), and the sulfur content is about half that of the Powder River region coal (table 2, last row). Furthermore, trace-element analyses of eight Mammoth coal samples from four localities (tables 3 and 4), when compared with Powder River region coal samples (last row, both tables), show that the Mammoth samples have about half as much of the commonly considered potentially toxic B, F, Mo, Pb, and Se. Toxicity hazards from environmental concentrations of these elements are discussed in Gough and others (1979). There may be fewer such hazards with the Mammoth coal than with the Powder River region coals. Only two elements occur in the Mammoth samples in considerably greater concentration than in the Powder River region (in fact, they are three to four times more abundant): Nb and Zr. The larger amounts of these elements, probably held in the heavy minerals, may be due to the Mammoth coal bed area having been closer to early Tertiary sources of volcanic ash than the Powder River area. Nb and Zr are unlikely environmental hazards.

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THICKNESS OF COAL BEDS IN FEET
THICKNESS
3–4
765+–845 feet
2½–6½
0–5½
5–16
0–6
0–3
0–6
0–8
0–8
890–1,210 feet
...ebo Shale Member (part)

...ition of the Mammoth coal bed and other ...l beds in the Bull Mountain coal field. ...and others (1917).

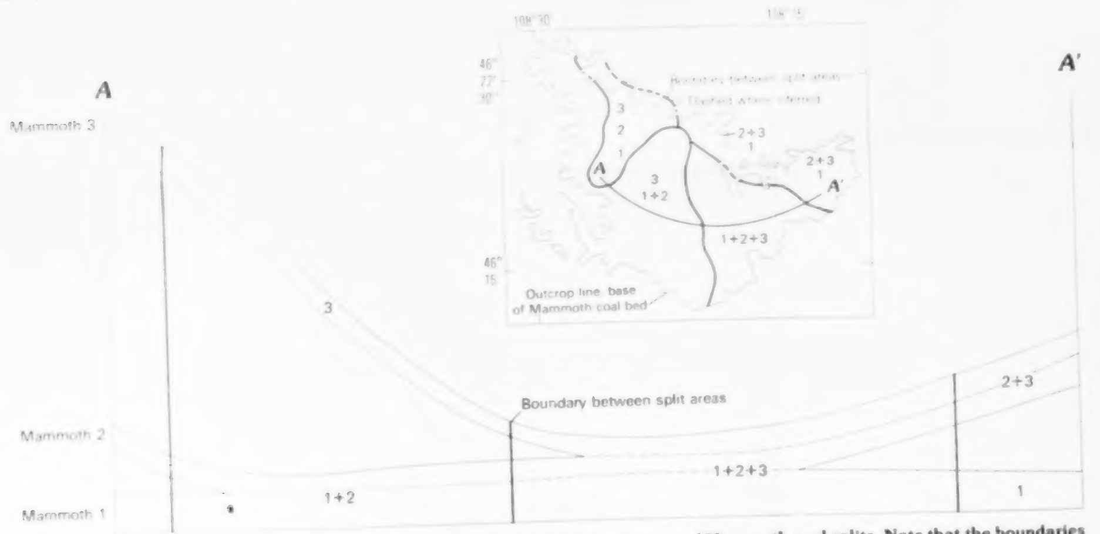

Figure 3.—Generalized cross section (see inset for location) showing designations of Mammoth coal splits. Note that the boundaries between split areas are drawn where a parting exceeds the thickness of the split either above or below.

SCALE 1:50 000
1 2 3 MILES
1 2 3 KILOMETERS
CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

...HS OF COAL SPLITS, COAL RESOURCES, AND COAL QUALITY— ...UE RIVER MEMBER OF THE FORT UNION FORMATION, ...FIELD, SOUTH-CENTRAL MONTANA

By
...arol Waite Connor
1989

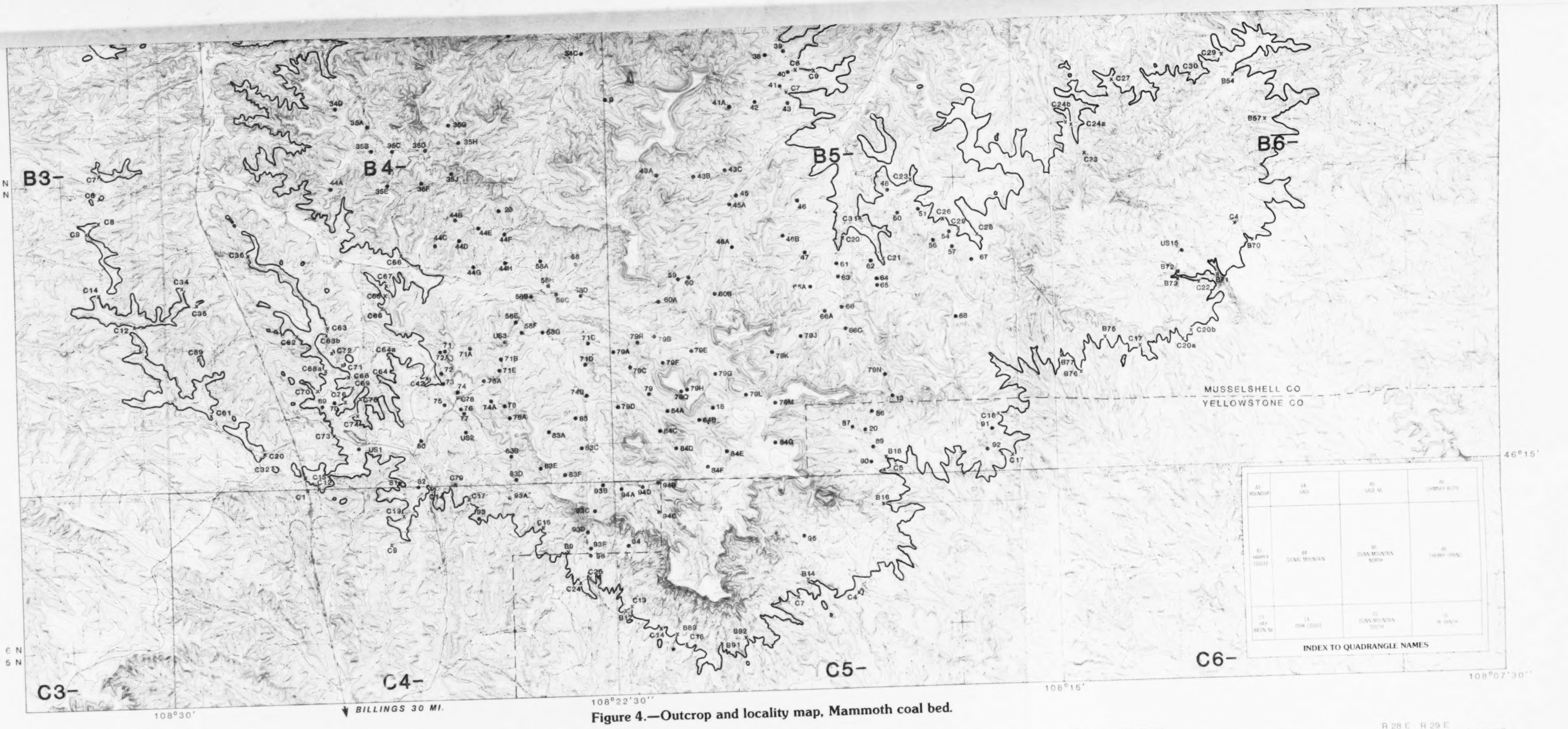

Figure 4.—Outcrop and locality map, Mammoth coal bed.

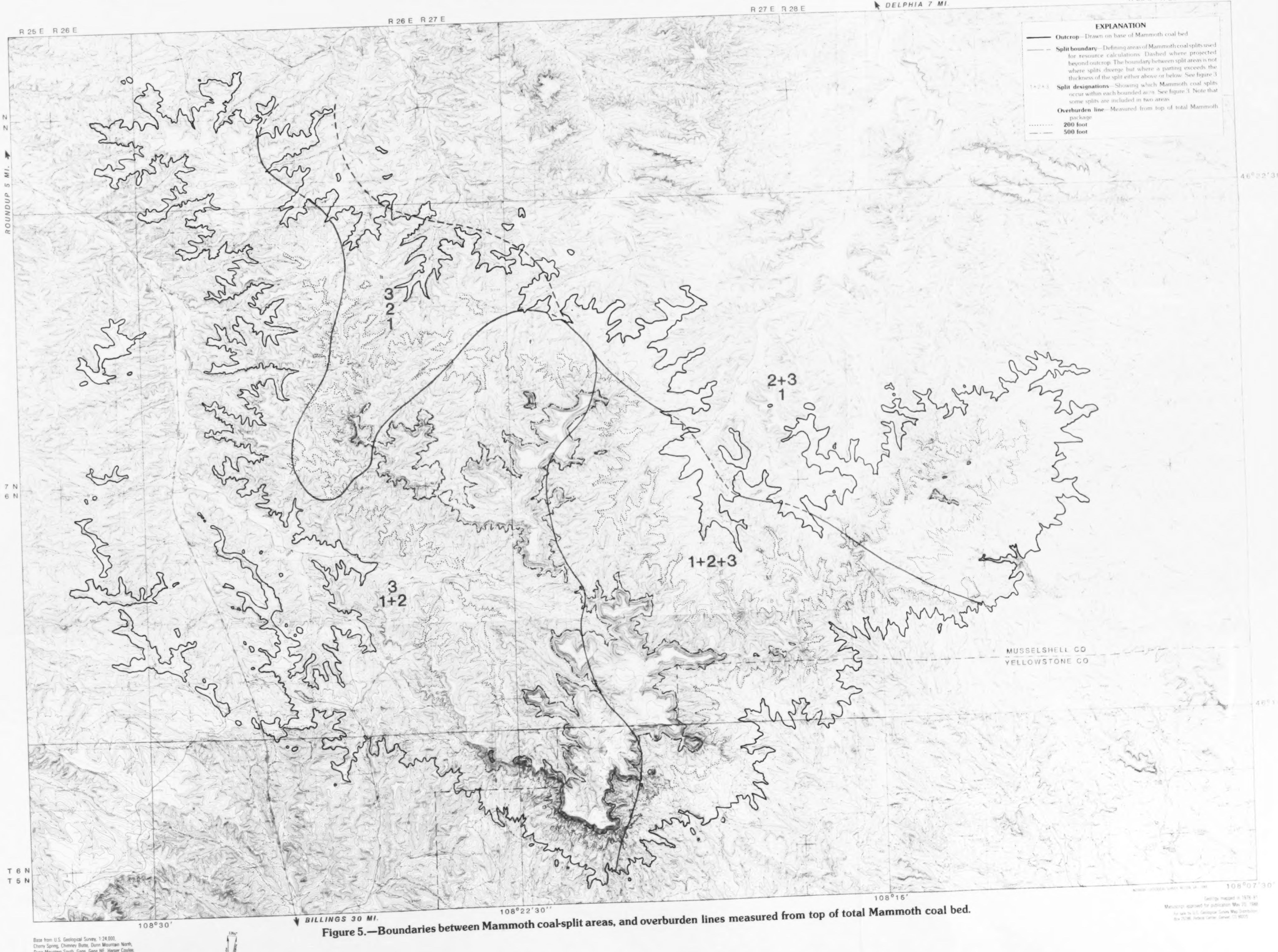
R 25 E
R 26 E
R 26 E
R 27 E
R 27 E
R 28 E
R 28 E
R 29 E
DELPHIA 7 MI.
ROUNDUP 5 MI.
T 8 N
T 7 N
T 7 N
T 6 N
T 6 N
T 5 N
46°22'30"
46°15'
3
2
1
2+3
1
3
1+2
1+2+3
MUSSELSHELL CO
YELLOWSTONE CO
BILLINGS 30 MI.
108°30'
108°22'30"
108°15'
108°07'30"
EXPLANATION
Outcrop—Drawn on base of Mammoth coal bed
Split boundary—Defining areas of Mammoth coal splits used for resource calculations. Dashed where projected beyond outcrop. The boundary between split areas is not where splits diverge but where a parting exceeds the thickness of the split either above or below. See figure 3
1+2+3
Split designations—Showing which Mammoth coal splits occur within each bounded area. See figure 3. Note that some splits are included in two areas
Overburden line—Measured from top of total Mammoth package
200 foot
500 foot

Figure 5.—Boundaries between Mammoth coal-split areas, and overburden lines measured from top of total Mammoth coal bed.

Base from U.S. Geological Survey 1:24,000, Cherry Spring, Chimney Butte, Dunn Mountain North, Dunn Mountain South, Gage, Gage NE, Hagan Coulee, Hay Basin NE, PK Ranch, Pole Coulee, Roundup, and Signal Mountain, unrevised advanced prints

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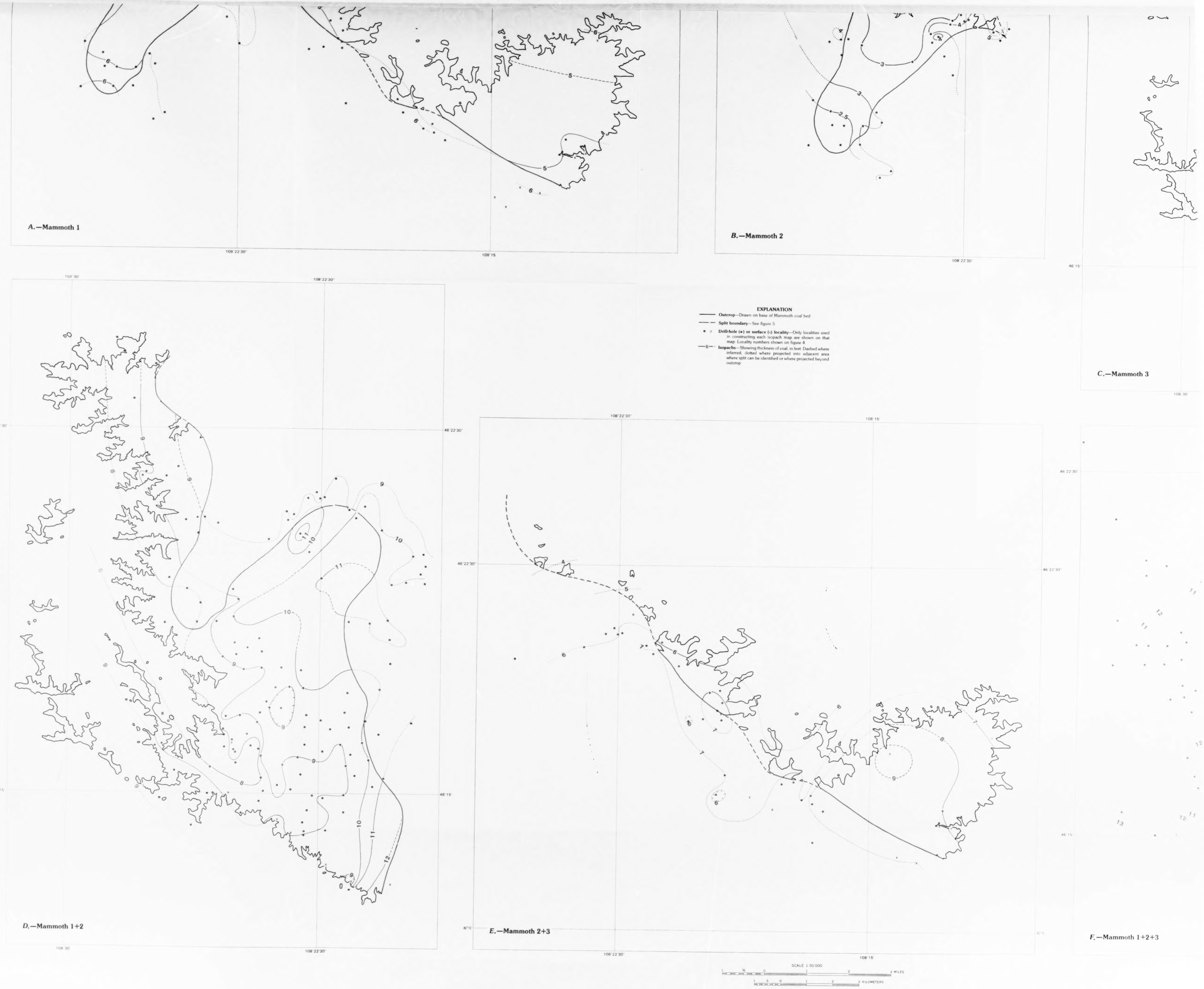
A.—Mammoth 1
B.—Mammoth 2
C.—Mammoth 3
D.—Mammoth 1+2
E.—Mammoth 2+3
F.—Mammoth 1+2+3
108°30'
108°22'30"
108°15'
46°22'30"
46°15'
SCALE 1:50 000
1 ½ 0 1 2 3 MILES
1 .5 0 1 2 3 KILOMETERS

EXPLANATION

Outcrop—Drawn on base of Mammoth coal bed

Split boundary—See figure 5

● x **Drill-hole (●) or surface (x) locality**—Only localities used in constructing each isopach map are shown on that map. Locality numbers shown on figure 4

—6—· **Isopachs**—Showing thickness of coal, in feet. Dashed where inferred; dotted where projected into adjacent area where split can be identified or where projected beyond outcrop

Figure 6.—Isopach maps of Mammoth coal splits.

MAPS SHOWING COAL-SPLIT BOUNDARIES, ISOPACHS OF COAL SPLITS, COAL RESOURCES, AND COAL QUALITY—MAMMOTH COAL BED, PALEOCENE TONGUE RIVER ME OF THE FORT UNION FORMATION, BULL MOUNTAIN COAL FIELD, SOUTH-CENTRAL MONTANA

By
Carol Waite Connor
1989

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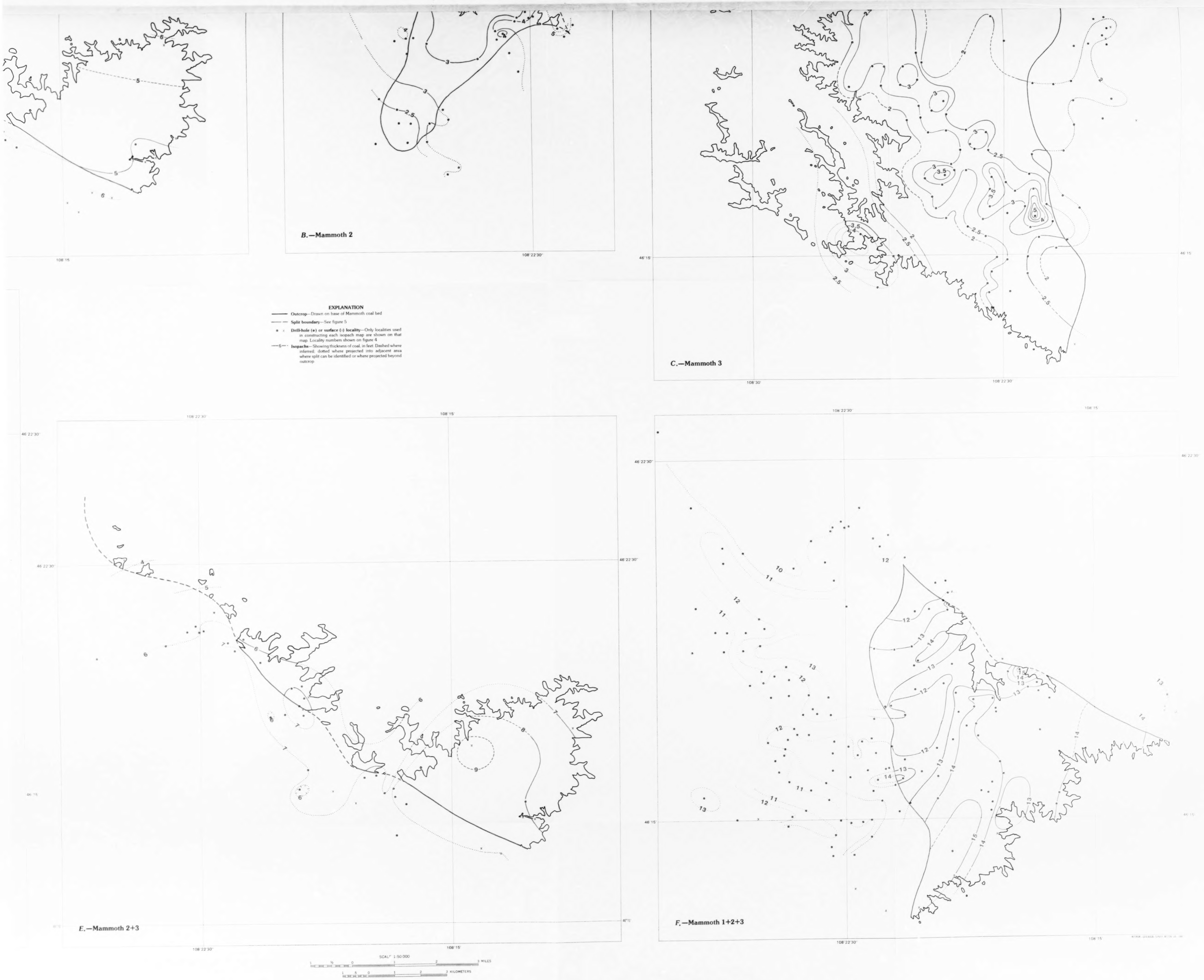
B.—Mammoth 2
C.—Mammoth 3
E.—Mammoth 2+3
F.—Mammoth 1+2+3
108°15'
108°22'30"
108°30'
46°15'
46°22'30"
EXPLANATION
Outcrop—Drawn on base of Mammoth coal bed
Split boundary—See figure 5
Drill-hole (●) or surface (x) locality—Only localities used in constructing each isopach map are shown on that map. Locality numbers shown on figure 4
Isopachs—Showing thickness of coal, in feet. Dashed where inferred; dotted where projected into adjacent area where split can be identified or where projected beyond outcrop
SCALE 1:50 000
3 MILES
3 KILOMETERS

Figure 6.—Isopach maps of Mammoth coal splits.

OWING COAL-SPLIT BOUNDARIES, ISOPACHS OF COAL SPLITS, COAL RESOURCES, AND COAL QUALITY—MAMMOTH COAL BED, PALEOCENE TONGUE RIVER MEMBER OF THE FORT UNION FORMATION, BULL MOUNTAIN COAL FIELD, SOUTH-CENTRAL MONTANA

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MAP GQ-1632

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U.S. GEOLOGICAL SURVEY

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By Mel A. Kuntz, Richard H. Lefebvre, and
Duane E. Champion

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